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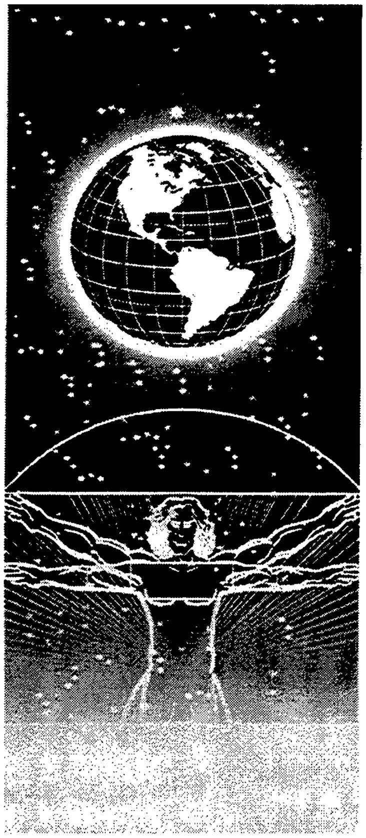

UNITED STATES AIR FORCE RESEARCH LABORATORY

Articulated Total Body Model Version V User's Manual

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FOR THE DIRECTOR

Thomas J. Moore

THOMAS J. MOORE
Chief, Crew Survivability and
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13. ABSTRACT (Maximum 200 words)

The Articulated Total Body (ATB) Model is used by the Air Force Research Laboratory (AFRL) and other organizations, companies and educational institutions for predicting gross human body response in various dynamic environments, especially automobile crashes and aircraft ejection with windblast exposure. The ATB-V Model introduces three new simulation tools: water force simulation, joint actuator simulation, and deformable segments, along with several minor changes. This User's Guide accompanies the release of the ATB-V version. It contains comprehensive information on the ATB model and its input structure. It is restructured completely from the previous version's User Guide with extensive modifications. Section 1 provides guidelines on how to install and run the ATB program. Section 2 gives a general description of the ATB model and its structure. An overview of the ATB input data and output files is provided in Section 3. The appendices contain example input and output files from the model.

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PREFACE

This report serves as a user's guide to present the start up procedures and general formulation of the Articulated Total Body (ATB) Model Version V, a dynamics simulation tool for the human body biomechanics in various dynamic environments.

To provide a complete user's guide, Obergefell, Gardner, Kaleps, and Fleck's "Articulated Total Body Model Enhancements, Volume 2: User's Guide," AAMRL-TR-88-043 (1), has been modified and incorporated into this report.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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1. INTRODUCTION

The Articulated Total Body (ATB) Model is used by the Air Force Research Laboratory (AFRL) and other organizations, companies, and educational institutions for predicting gross human body response in various dynamic environments, especially automobile crash and aircraft ejection with windblast exposure. The ATB Model originated from the Crash Victim Simulation (CVS) program (2). Aerodynamic force application and a harness belt capability were added to the CVS program by Calspan Corporation in 1975 for AFRL (3), and the resulting program became known as the ATB Model. In 1980, Calspan made a number of modifications to the ATB Model, combining it with the then-current 3-D Crash Victim Simulation program to form the ATB-II Model (4). Complete documentation of the program through the ATB-II version was performed by Calspan (5, 6, 7, 8). The next version, ATB-III, which included improvements made by J&J Technologies, Inc., was generated to model the body response to windblast for AFRL (9). The version ATB-IV (1, 10, 11) was released in 1988 with a number of additional efforts being made to improve various aspects of the ATB-III Model, with emphasis on its capability to simulate aircraft ejection with windblast exposure, as well as complex automobile accidents.

The ATB-V Model introduces three new simulation tools: water force simulation (12), joint actuators (13), and deformable segments (14). A major change has been made to the data arrays to increase the maximum number of segments, planes, and contact definitions. A new type of structured ASCII graphics data output file has been designed for use by the Interactively Manipulated ATB Graphical Environment (IMAGE) program (15) and the VIEW program (16). It has a more efficient format that the original graphics data file and mikes troubleshooting easier for the IMAGE and VIEW programs. Several outdated features, such as the restart and plotting options, have been deleted from the ATB Model. There are also a number of other minor modifications and input/output enhancements, such as enhanced HIC value computations, clarified joint property definitions, calculation of moments of inertia and principal axes for a set of segments, and control of individual contact output.

This User's Guide accompanies the release of the ATB-V version. It contains comprehensive information on the ATB Model and its input structure. It is completely restructured from the previous version's User's Guide with extensive modifications. Section 2 gives a general description of the ATB Model and its structure. An overview of the ATB input data and output files is provided in Section 3. The appendices contain example input and output files from the model.

1.1 Installation and Hardware Requirements

The ATB Model is written in FORTRAN so it can be run on a number of platforms, including personal computers and UNIX workstations. The software package includes the FORTRAN source code, the PC executable, and example simulation files. For installation information, please see the file *readme*.

The PC executable requires a 486 or higher personal computer (PC) supporting MS-DOS mode operation. It is recommended that the PC have at least 8 MB RAM and 5-10 MB free hard disk space. The program is typically distributed on 3.5-inch high density (1.44 MB) diskettes.

1.2 Running the ATB Model --- An Example

In order to demonstrate the procedure for running the program, the example file shipped with this program is used as the input file in the following discussion. It is listed as *example.ain* on the shipment disk and is presented in the Appendix. This example simulates a sled test with a male subject in a seated position facing forward.

1.2.1 Programs and I/O Files in the ATB Model

The executable program of the ATB Model is named *atbv-x.exe*. There are two other executable files shipped together with the ATB Model. One is the GEBOD program, *gebodx.exe* (17), which is used to generate the human and dummy data sets for the ATB input file, i.e., the B cards of the input file. The other is the VIEW program *viewx.exe* (16), which is a graphics program used to generate the pictures of body motion based on the simulation results. An alternative graphics program, called IMAGE (Interactively Manipulated ATB Graphical Environment), is available on Silicon Graphics workstations to generate solid object animations. Figure 1 presents the organization among these programs and their corresponding input and output files.

When using the ATB Model for occupant modeling, one typically uses the GEBOD program to generate the occupant segment and joint data. The GEBOD program creates the B cards for ATB's input file and saves them in a file with an *.ain* extension. The generated B cards are inserted into the input file, which also has the extension *.ain*. (The ATB Model's input file requires an *.ain* extension following the file name.) In the example case, it has the full filename *example.ain*. Upon successful execution of the program, a set of output files is generated with a user-chosen filename and a set of unique extensions to distinguish them. There are three kinds of extensions assigned to the output files, *.aou*, *.tp1* or *.sa1*, and *.t??*. The question mark stands for a number character. The file with the *.aou* extension is the main output file containing all the input data, clearly labeled, and extensive run time information. The file with the extension *.sa1* or *.tp1* is the data file used by the VIEW and IMAGE programs for graphical image generation. The set of files with *.t??* are the tabular time history outputs of user-chosen simulation data, such as segment accelerations, contact forces, joint forces and torques, etc. The number of time history files is defined by the user input.

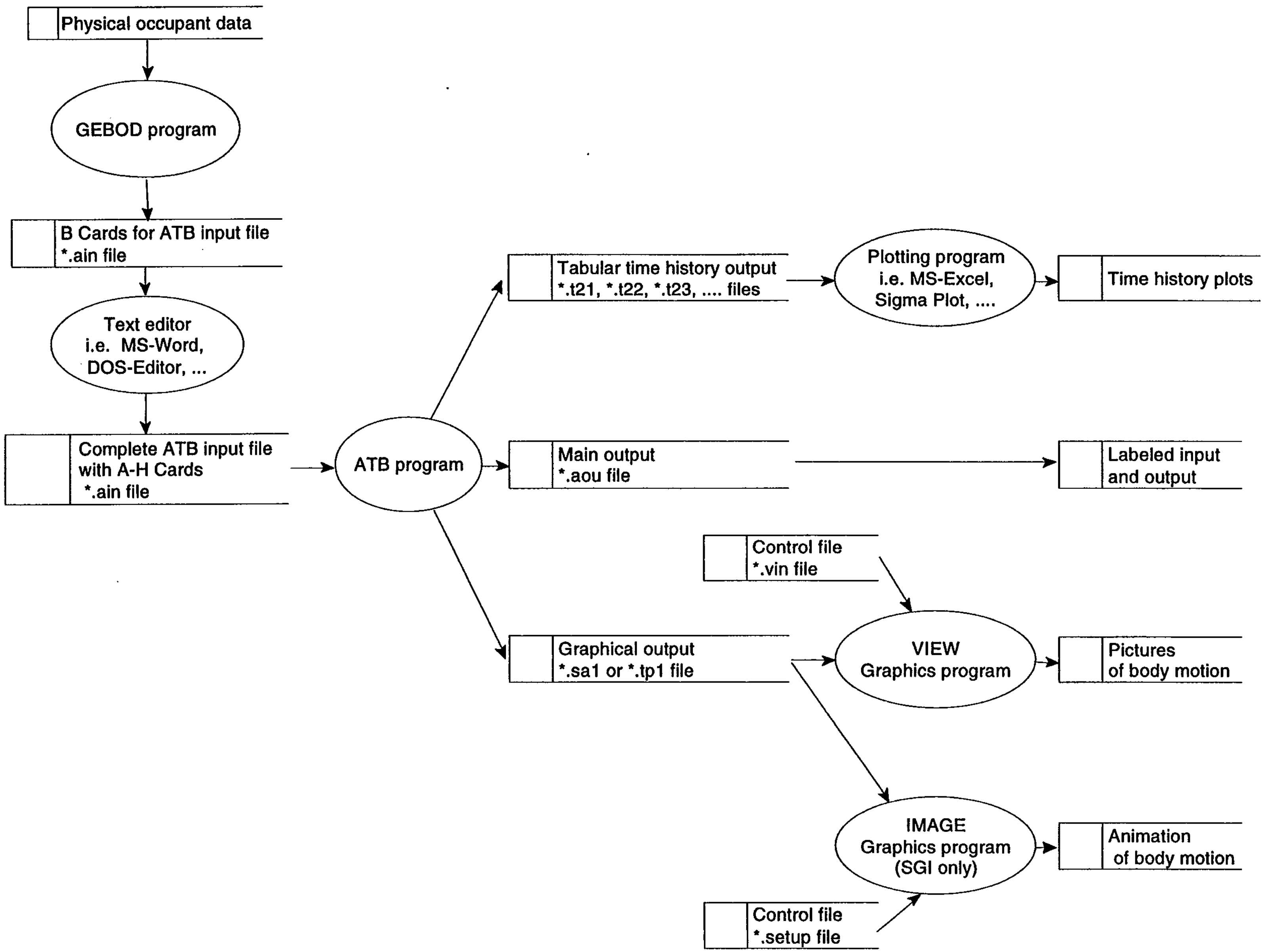

Figure 1. Organization of ATB Program and Files

1.2.2 Running ATB on PC

To start running the program, make sure you are in MS-DOS shell or mode and type:

atbv-1

then press [Enter]. You will be prompted by the message "ENTER INPUT FILENAME, EXTENSION .ain IS ASSUMED:". To run the input file *example.ain*, type in:

example

then press [Enter]. You will be prompted by another message "ENTER FILENAME FOR ALL OUTPUT FILES, EXTENSIONS WILL BE ASSIGNED:". Type in:

example

then press the [Enter] key. You can choose another output file name instead of *example* if you wish. The program will start running and generate the output files. If no error occurs, the program will terminate automatically with a message "COMPLETED ATB SIMULATION" displayed on the screen.

The ATB Model also has a workstation version running under UNIX. The running procedures are exactly the same as for the PC version.

1.2.3 Runtime Error Message and Troubleshooting

There are two types of runtime error messages. One is from the compiler or operating system. For these errors, consult the relevant reference manuals. The other type of error message is generated from within the ATB program, in which case a stop number will be displayed on the computer monitor. You can find the cause of this stop by referencing the numbered stop list attached at the end of the ATB Input Manual.

To troubleshoot a simulation problem, the main output *.aou* file often offers a good indication. This file first prints all the input data with labels for each variable. If an error occurs in an input card, the output stops near the error card. Therefore, it indirectly indicates that there are problems in the next few input cards, such as wrong format or inconsistency with data in earlier input cards.

Once the program is running, extensive dynamic and kinematic data are printed to the *.aou* file at each successful time step. These include segment linear and angular positions, velocities, and accelerations, joint forces and torques, and external forces and torques. Additionally, information about when the belt reference points are being dropped and picked up, and convergence of the integrator is also included in the *.aou* file. If an error occurs, the output stops and an error message is usually printed out at the end of the file.

2. GENERAL FORMULATION OF THE ATB MODEL

The Articulated Total Body (ATB) Model is primarily designed to evaluate the three-dimensional dynamic response of a system of bodies when subjected to a dynamic environment consisting of applied forces and interactive contact forces. Although the ATB Model was originally developed to model the dynamic response of crash dummies and, with later modifications, the response of the human, the ATB Model is quite general in nature and can be used to simulate a wide range of physical problems that can be approximated as a system of connected or free bodies. The ATB Model has been used to model such widely diverse physical phenomena as human body dynamics, the motion of the balls in a billiards game, and the transient response of an MX missile suspended from cables in a wind tunnel. Version V further expands the model's capabilities to include water force simulation with personal flotation devices, robotic motion simulation, and deformable segment modeling. This flexibility in the ATB Model can cause the application of the ATB program to appear to be overly complex to the uninitiated user. The purpose of this section is to present the primary program features that should be mastered to utilize the ATB program. Throughout this discussion a number of input variables will be mentioned. A complete description of these and all input variables is presented in the ATB Model Input Manual file included with the program. For a more detailed discussion of how the model uses these data, the various theory manuals are recommended (1, 3, 4, 9, 10, 11, 18, 13, 14).

2.1 Chain Structure of the ATB Model

The system to be simulated by the ATB Model can be made up of one or more segments which may be connected or free. To avoid confusion between the overall body or object to be modeled and the individual rigid or deformable bodies that make up the overall body, throughout this report the term "segment" will henceforth be used to refer to the individual rigid or deformable bodies and the term "body" will refer to the overall body or object to be modeled. The approach used in the ATB Model is to consider the body as being segmented into individual rigid or deformable segments. Segments are assigned mass and moments-of-inertia and are joined at locations representing the physical joints of the human body, such as the shoulder joint or the knee joint.

The system can be made up of a number of free segments, bodies of segments coupled together at joints, or a combination of both. A body made up of coupled segments should form an open chain or a tree structure. While this is not an absolute requirement, closed chains may encounter computational problems. One must also be careful not to exceed the maximum number of segments (**MAXSEG**) specified by the dimension statements of the program variables (See ATB Model Input Manual for a list of program parameters and their current values).

The total number of body segments (**NSEG**) and total number of joints (**NJNT**) used to compose all the bodies in a simulation are input parameters. Figure 2 depicts a typical 17-segment (**NSEG** = 17) model with 16 joints (**NJNT** = 16) that is commonly used in car crash and aircraft ejection simulations for modeling humans and dummies. The number of segments can be readily varied in

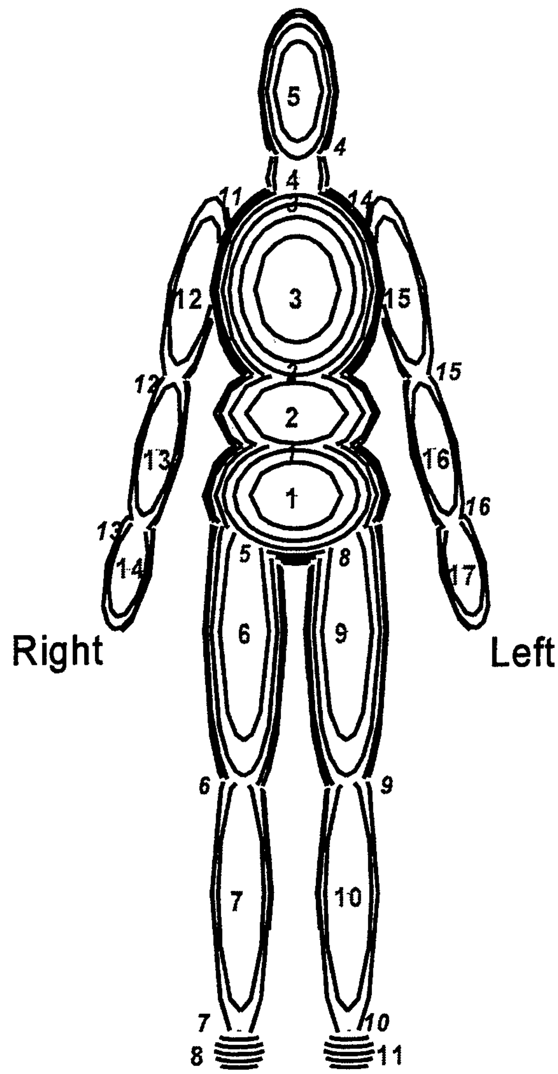

Figure 2. Standard Body Setup

the input without any code modifications for up to **MAXSEG** segments. Variations of the 17-segment body have combined the forearms and hands for a 15-segment body (**NSEG** =15 and **NJNT** = 14), added shoulder segments, or used different torso configurations.

Whatever the specific body model, the procedure to construct the body remains the same. The body is assembled as a chain of individual segments. The body can take on a tree-like structure, with several chains (here representing the arms and the legs) branching out from several connected segments.

The body segments and joints are assigned identification numbers, I for the segments ranging from **1** to **NSEG** and J for the joints ranging from **1** to **NJNT**. The assignment of the identification numbers is defined by the order in which the segments and joints are listed in the input. They are

used, along with the one-dimensional array, JNT(J) for J = **1** to **NJNT**, to define the connectivity of the segments. Segment 1 and the first segment of any body are considered reference segments. Although the reference segment may be any of the body segments, it has been found that, for this 17-segment body model, the lower torso is the best choice for the reference segment. When the ATB Model was first developed, the head was chosen as the reference segment. It was found that the erratic accelerations of the head caused numerical problems with the program integrator and that it was more beneficial to use a more stable, nonextremity segment, hence the choice of the lower torso as the reference segment. A generalization of this result is the recommendation that, regardless of the body model, the reference segment be chosen to be one that undergoes the smallest accelerations of any of the segments and/or is the heaviest segment. Use of the lower torso as the reference segment also makes positioning the body into a seat easier.

Once the lower torso is selected as the reference segment and is designated as segment number 1, the remaining segments should be numbered in an order moving away from the reference segment. The left side of Table 1 shows the segment numbers for this 17-segment body. Each segment can also be given a symbol name of up to four alphanumeric characters for output labeling purposes, as shown in column 3. The connectivity of the segments is provided by the joints. The JNT(J) array provides the relationship between the segments and joints. When JNT(J) = I, the joint J connects segment I with segment J + 1. In other words, JNT(J) stores the segment number of the proximal segment for the Jth joint. In the context of the ATB Model, a proximal segment is the segment nearest to the reference segment, whereas a distal segment is the segment further from the reference segment. For example in Table 1, joint J = 4 (head pivot) connects segment J + 1 = 5 (head) to segment 4 (neck). Therefore JNT for joint 4 is 4. Another example is joint J = 5 (right hip) which connects segment J + 1 = 6 (right upper leg) to the lower torso, segment 1. Therefore, JNT for joint 5 is 1.

Successive segments and joints are assigned with the provision that each joint J connect segment J + 1 to a previously assigned segment. If the J + 1 segment is a reference segment for an additional body, JNT(J) is set to 0. This signifies that joint J will be a null joint and that segment J + 1 will be the reference or base segment of another body. This permits the specification of multiple bodies that are disconnected or free.

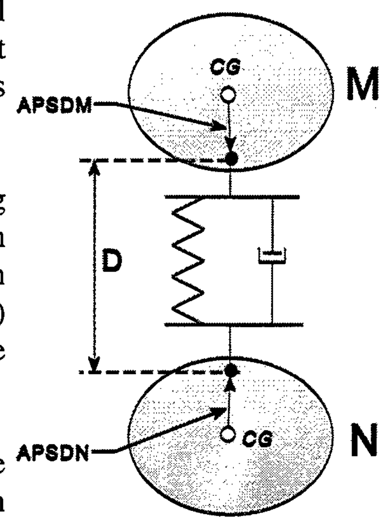

Figure 3. Spring-Dampers

Besides using a joint, two segments can also be connected by using a spring-damper combination, as shown in Figure 3. One situation where you might like to use a spring-damper combination is when you want to model the thorax as two segments (spine and sternum) connected by a spring-damper combination in order to evaluate chest deflection.

Ellipsoids are used to represent the physical appearance of the segments. They are the outer surfaces of the segments, and can interact with the environment. The B.2 cards in the input file are

Table 1 Segment and Joint Assignments and Connectivity

I	SEGMENT NAME	SYMBOL	J	JOINT NAME	SYMBOL	JNT(J)	CONNECTS SEGMENTS
1	Lower Torso	LT	1	Pelvis	P	1	1 - 2
2	Center Torso	CT	2	Waist	W	2	2 - 3
3	Upper Torso	UT	3	Neck Pivot	NP	3	3 - 4
4	Neck	N	4	Head Pivot	HP	4	4 - 5
5	Head	H	5	Right Hip	RH	1	1 - 6
6	Right Upper Leg	RUL	6	Right Knee	RK	6	6 - 7
7	Right Lower Leg	RLL	7	Right Ankle	RA	7	7 - 8
8	Right Foot	RF	8	Left Hip	LH	1	1 - 9
9	Left Upper Leg	LUL	9	Left Knee	LK	9	9 - 10
10	Left Lower Leg	LLL	10	Left Ankle	LA	10	10 - 11
11	Left Foot	LF	11	Right Shoulder	RS	3	3 - 12
12	Right Upper Arm	RUA	12	Right Elbow	RE	12	12 - 13
13	Right Lower Arm	RLA	13	Right Wrist	RW	13	13 - 14
14	Right Hand	RH	14	Left Shoulder	LS	3	3 - 15
15	Left Upper Arm	LUA	15	Left Elbow	LE	15	15 - 16
16	Left Lower Arm	LLA	16	Left Wrist	LW	16	16 - 17
17	Left Hand	LH					

used to define the segments. Each card contains the segment's weight, principal moments of inertia, its ellipsoid's semi-axes and center offset from the center of gravity (CG). The ellipsoid's semi-axes define the size of the segment. Following the B.2 cards, a set of B.3 cards gives the location of each joint. For the Jth joint, the B.3 card has the value of JNT(J) and the joint location with respect to each of the two connected segments. The B cards can be automatically generated using the GEBOD program for human and dummy subjects.

Although human and dummy subjects are most often simulated in the ATB Model, there is no limitation on the type of subject. For example, a MERLIN robot arm modeled in six segments and five joints (13) has been simulated. In this case, the user defined the chain structure and built B.2 and B.3 cards manually instead of using the GEBOD program. The program also allows multiple

bodies as long as the total segment number does not exceed **MAXSEG**. For example, two (driver and passenger) occupants' motions in an accident can be simulated together. The user needs only to generate the B cards for both occupants and combine them, with a null joint between. It should be noted that there are *two* reference segments in this case, the lower torso segments of the driver and the passenger. A body may also consist of only one segment. An example is a vehicle simulation of a pickup truck's rollover (18). The body is the pickup truck represented by a single segment. Its outer shape is described using multiple contact hyperellipsoids (see section 2.3.2) attached to the segment (Figure 4) instead of only one ellipsoid.

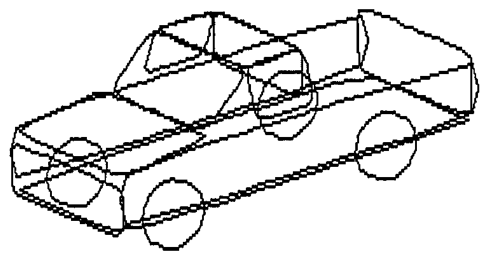

Figure 4. One-Segment Vehicle

In addition to rigid segments, the ATB Model accepts deformable segments created by finite element analysis tools. The need for a deformable segment arises when an accurate response is required for relatively "flexible" segments, such as the human neck, or where local segment vibrations occur. To use this option, the user must first develop a finite element model of each deformable segment and perform modal analysis to determine their selected natural frequencies and mode shapes. The data required by the ATB Model for each deformable segment are then placed in separate data files. Each deformable segment's finite element data file consists of node numbers and coordinates, natural frequencies, and mode shapes. Names of these files are input on the B.1.b card. The procedure for developing deformable segment models is outlined in Appendix B.

2.2 Reference Coordinate Systems

The ATB Model utilizes many reference coordinate systems, with respect to which points in space and directions are calculated within the program. Considerable flexibility in the choice of coordinate systems and their specification for both input and output are available. The primary coordinate systems used in the model are the inertial, vehicle, local body segment, segment principal moment of inertia, joint, and contact ellipsoid reference coordinate systems. The specification of each reference coordinate system requires an origin and a direction cosine matrix which relates one reference coordinate system to another. The direction cosine matrix is usually initially specified by three rotation angles, yaw, pitch, and roll, as depicted in Figure 5. These are consecutive body fixed rotations about the Z, Y, and X axes, respectively. All coordinate systems discussed in this section are orthogonal.

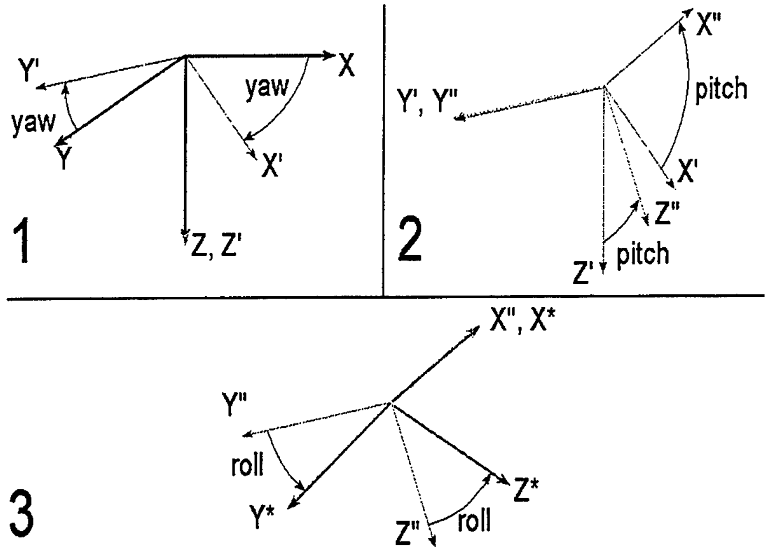

Figure 5. Yaw, Pitch, and Roll

2.2.1 Inertial Reference Coordinate System

The ATB Model assumes that the coordinates of the origin of the inertial reference system are zero and all other coordinate systems are specified with respect to this system. The user may place the origin of the inertial reference coordinate system at any convenient point from which his data are referenced. The orientation is partially specified by defining which way is down by the values supplied for the components of the gravity vector. It has been customary to supply (zero, zero, g) as the components of the gravity vector to specify that the positive Z_I axis is pointing downward, as shown in Figure 6. Hence, in terms of a standing man, the force of gravity would be pointing in the direction from his head to his feet. Typically, the forward direction (pointing from the back of the standing man to his chest) is taken as the positive X_I axis and (by the right hand rule) the positive Y_I axis is in the lateral direction (pointing from the standing man's left side to his right side).

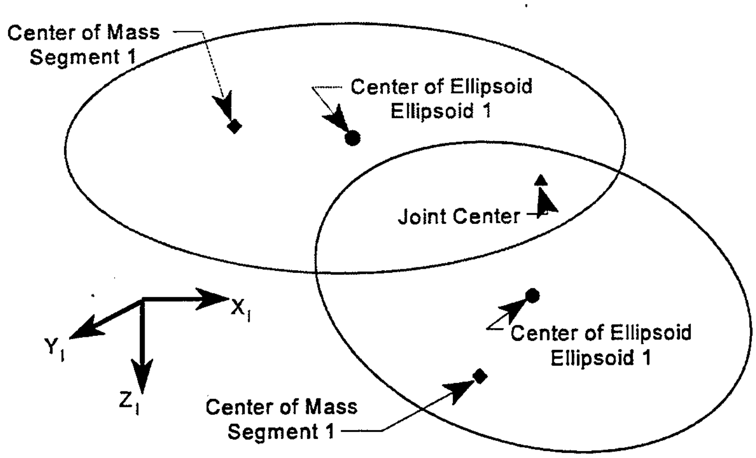

Figure 6. Inertial (Ground) Coordinate System

However, the user may specify any frame of reference that suits their application, one with which they are more familiar, or in which their input data have been measured.

It is sometimes necessary that contact surfaces (planes or ellipsoids) be located with respect to the inertial reference coordinate system, e.g., the ground for pedestrian simulations. Since the program assumes that contact surfaces are associated with segments, a special segment identification number (**NGRND**) is used within the program for this purpose. **NGRND** is the largest segment number used by the program and is assigned the value **NGRND** = **NSEG** + number of airbags (**NBAG**) + number of vehicles + 1 and corresponds to the inertial coordinate system. The linear position and velocity for this segment are set to zero and its direction cosine matrix is an identity matrix throughout the duration of the simulation. This permits the use of segment **NGRND** for the attachment of contact surfaces.

2.2.2 Vehicle Reference Coordinate Systems

Up to six prescribed motions can be defined. These can be prescribed motions of segments defined earlier in the B cards, or of vehicles. The primary vehicle is the last prescribed motion defined and is different from the other vehicles in that it serves as the default reference coordinate system for several types of input and output. Most of the contact panels are usually defined with respect to this system and much of the output can be produced with respect to this system. The origin of each vehicle coordinate system is arbitrary, and any convenient reference point may be chosen to which input and output data would be most meaningful. The frames of reference (the directions of the positive X, Y, and Z axes) are arbitrary and should be chosen to accommodate input data.

A special segment identification number is assigned for each of the vehicles where **NVEH1** = **NSEG +1**, **NVEH2** = **NSEG** + **2**, etc. so that each vehicle may be treated like other segments for contact surface specifications. However, no matter how large the computed contact forces and torques are on these vehicle segments, the prescribed motion of the vehicle segment will not change. See section 2.5 for more information.

2.2.3 Body Segment Reference Coordinate Systems

Each body segment has a local reference coordinate system, sometimes referred to as the segment geometric coordinate system. Each body segment has a mass and principal moments of inertia. The local reference coordinate system, marked with subscript 'L' in Figure 7, has its origin at the segment mass center. The principal moment of inertia axes, subscripted with 'P', are specified with respect to the local reference system. The contact (hyper) ellipsoid's origin and orientation, represented by the ellipsoid coordinate system in Figure 8, are also specified with respect to the local reference system. There is no direct association within the ATB Model of the segment inertial properties and the contact (hyper) ellipsoid. Unlike the vehicle segments, a body segment's kinematics are computed based on the dynamic interactions the body segment experiences during a simulation. A body segment can be given an initial position, orientation, and linear and angular velocities, and its motion is then computed for the remainder of the simulation subject to any imposed constraints (e.g.

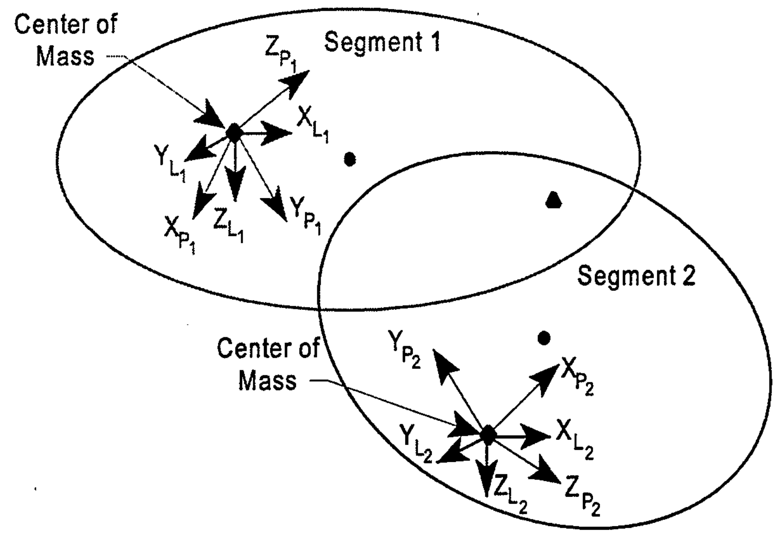

Figure 7. Segment Local and Principal Moment of Inertia Coordinate Systems

number and type of joint) and applied forces. The motion of the body segments cannot be specified unless the body segment is a reference segment. The orientation of the segment local reference coordinate systems can be arbitrarily defined. The standard convention has been to choose the axes so that when the body is in an upright standing position with arms at the side, the Z axis is downward, the X axis is to the front, and the Y axis is to the body's right.

The segment center of gravity is indirectly determined through the segment's joint coordinates because these coordinates are given in the local reference systems by Card B.3. If the segment is deformable, there is no meaningful local reference system because the center of mass keeps changing when deformation occurs. Its joint locations are specified by the node numbers.

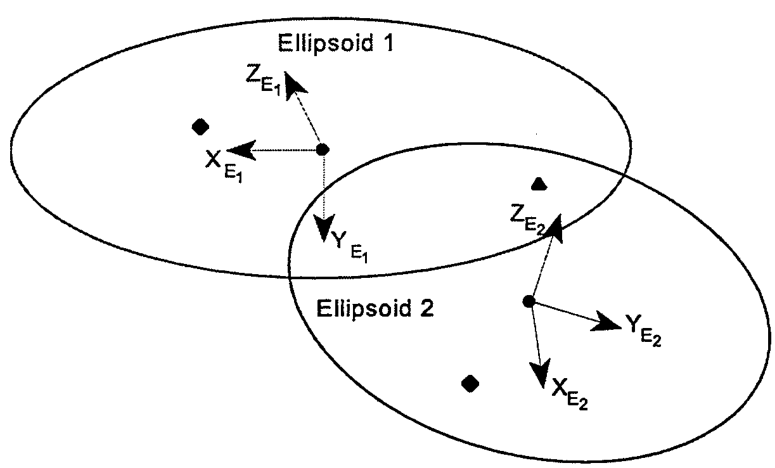

Figure 8. Ellipsoid Coordinate Systems

A contact ellipsoid is associated with each segment and is used for interactions with the environment. The ellipsoid number is the same as the segment number of the associated segment. The ellipsoid coordinate system origin is located at the ellipsoid center and its axes are the ellipsoid semiaxes. The ellipsoid coordinate system can be translated from the segment local coordinate system, but cannot be rotated in the B cards. In order to rotate the ellipsoid axes, the ellipsoid must be redefined in the D.5 cards (additional (hyper)ellipsoids), using the original ellipsoid number. See Section 2.3.2.

The dynamic equations in the ATB Model are solved in terms of the principal axes. All three-dimensional bodies have an inertia tensor. Six of the nine inertia tensor elements are independent, therefore it is a second order, symmetric tensor. Any body has three principal directions for which there are three moments of inertia, corresponding to the diagonal elements of an inertia tensor when all the off-diagonal terms are equal to zero. The segment principal coordinate system axes correspond to the three principal directions, therefore only the three principal moments of inertia must be specified.

The principal axes are fixed with respect to the segment local reference axis. After input, the ATB model converts all data points expressed in the local segment reference coordinate systems to principal coordinates and, prior to output, back to the local segment reference coordinate systems in a manner that is transparent to the user. Therefore, when the input description refers to local segment reference, the local and not the principal moment of inertia reference coordinate system is implied. Note that, for some cases where the principal axes are aligned with the local reference axes, the two are coincident.

2.2.4 Joint Reference Coordinate Systems

In the ATB Model, the maximum number of joints is **MAXJNT**. A complete definition of a joint consists of geometric location, joint coordinate systems, type of joint, and mechanical properties.

Based on the mathematical formulations in the joint force and torque computation subroutines, it is necessary to define two coordinate systems for a joint, one rigidly attached to each of the two segments that are connected by the joint, as shown in Figure 9. As described in the previous

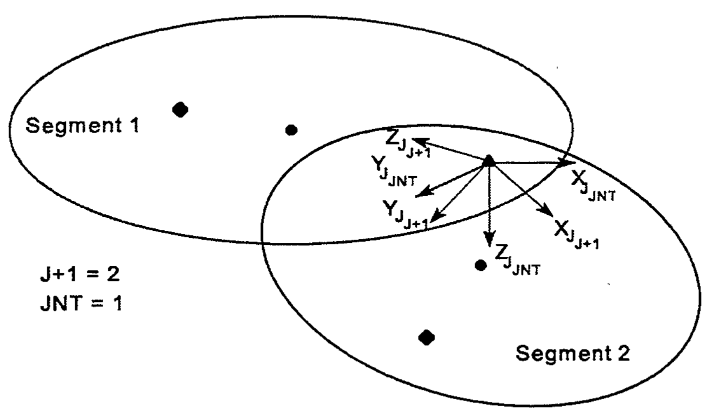

Figure 9. Joint Coordinate Systems

sections, these two segments are identified as segments JNT (J) and J+1 for joint J. The origin of each joint reference coordinate system (or the location of the joint) is specified in the segment local reference coordinate systems of both segments JNT (J) and J+1. The orientations of the joint axis systems are specified by rotation angles (yaw, pitch, and roll) from the local reference systems of both segments. Note that once the two joint coordinate systems are defined, they are fixed in their corresponding segments and do not move relative to the segments. In *example.ain*, Cards B.3.a and B.3.b specify the joint origin locations and joint coordinate system orientations, respectively.

In Card B.3.a, the parameter IPIN is used to specify the joint type. Figure 10 shows all the joint types used in the ATB Model. Among them, the null joint can be used to disconnect two bodies within the required chain structure. For example, in an automobile crash simulation with two occupants, the first occupant's joint data are followed by a null joint and then the second occupant's joint data. The ball-and-socket joint is suitable for modeling a human shoulder joint and a pin joint is suitable for an elbow joint. The Euler joint is a type of joint which has full three-dimensional motion and at the same time allows the user to impose various constraints on its motion. An Euler joint is used in the modeling of the Hybrid III dummy's shoulder joint. The slip-type joints can be used in spine and neck modeling, to account for compression and tension.

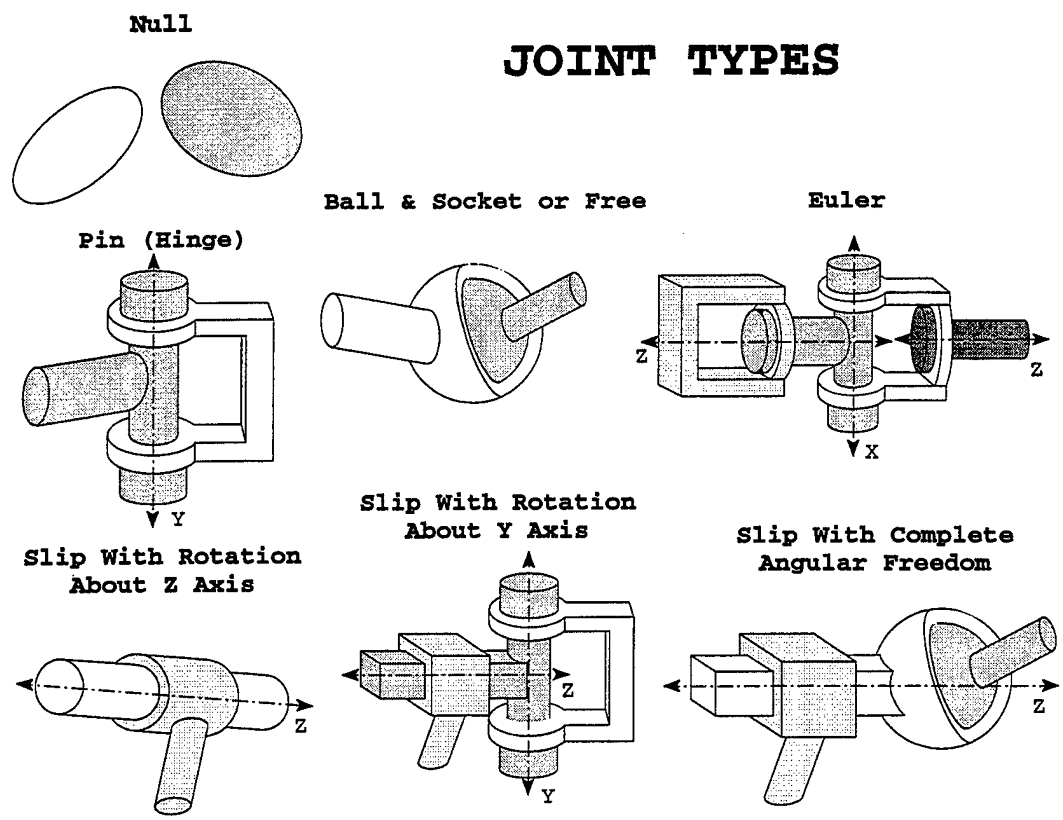

Figure 10. Joint Types in the ATB Model

Joint forces and torques are computed by the ATB program as a function of the relative orientation of the two joint coordinate systems at the joint, i.e., the joint angle and angular velocity. The joint coordinate system associated with the JNT (J) segment is used as the base reference system for determining the joint parameters. For the pin joint, the Y axis is the axis of rotation. For the ball joint or free joint, flexure (theta) is the angle between the two Z axes, while azimuth (phi) is the angle between the base X axis and the projection of the segment J+1's Z axis into the X-Y base plane, and twist is rotation about the base Z axis. For the Euler joints, precession, nutation and spin are defined as the rotations about the Z, X, and Z axes respectively from the base joint coordinate system to the segment J+1's joint coordinate system. For the slip joint, the linear motion is defined along the base Z axis. Further descriptions of the joint types and their axis systems can be found in References 5 and 10.

The joint mechanical properties define the relationship between the joint resistive torque and the joint angle and angular velocity. These properties include the joint spring, viscous, and coulomb torque characteristics. Two options are available for specifying the spring torques. Figure 11 shows the joint spring torque function for the first option. In this definition, a linear torque vs. joint angle is prescribed until a specific, user-defined, joint stop angle, S_5, is reached. For angles greater than the joint stop, a quadratic or cubic restoring torque is added. Using this option, the torques are symmetric about the zero position. Alternatively, the user has the option to define a joint resistive torque function that depends on two joint angles, flexure and azimuth, by using the E.7 card to construct a two-dimensional matrix data array. The joint's B.4 card then references the function in the E.7 card for the joint spring characteristics instead of using the coefficients in the B.4 card. The spring characteristics of the hip and shoulder joints, etc., in *example.ain* are defined using E.7 cards. Figure 12 shows the viscous and coulomb torques, defined as functions of joint angular velocity. These functions are used with both spring torque options and are defined in *example.ain* using the B.5 cards.

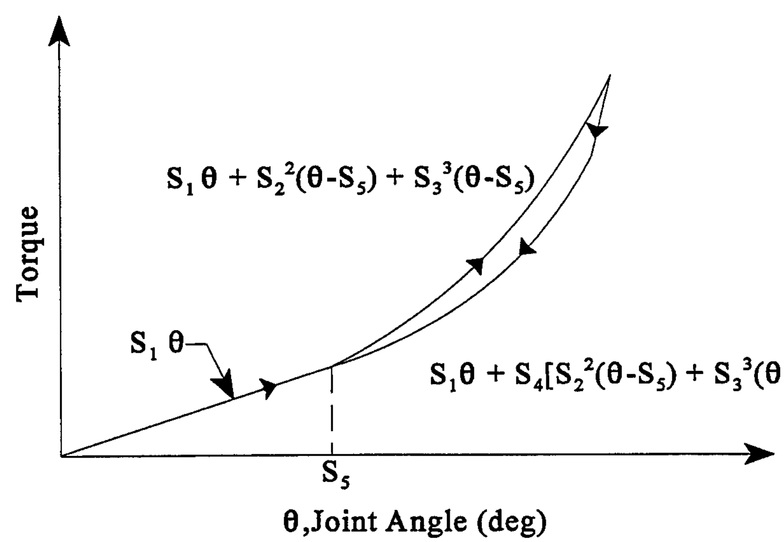

Figure 11. Joint Spring Torque

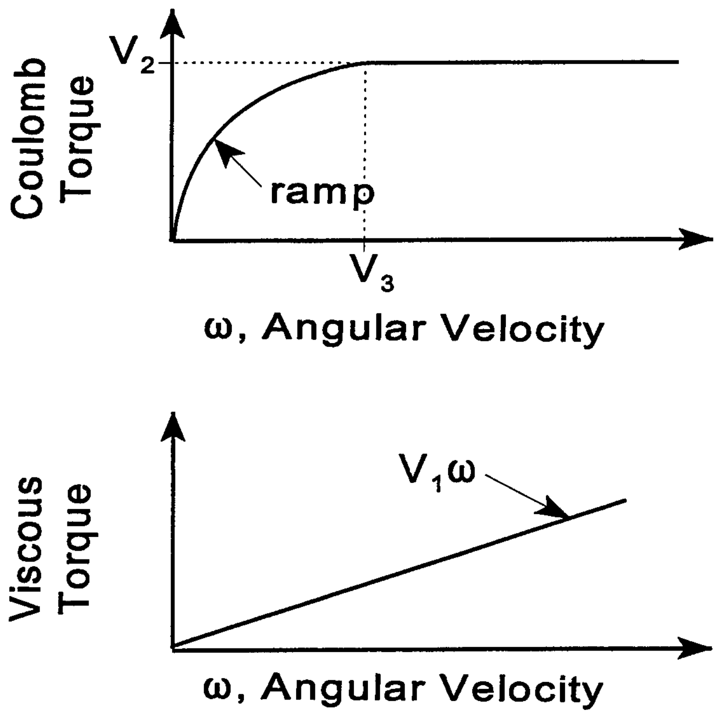

Figure 12. Joint Torques

Besides resistive-type torque, the joint actuator option allows active torques to be applied at the joints, driving the joints to prescribed target angles. It can be used to simulate the joint actuators on a robot or active muscles. The basic computational scheme uses feedback control logic. The F.10 card is used to define a relationship between the joint target angle functions and their corresponding active torques' control gain functions. For detailed information, Reference 13 is recommended.

2.3 Environment Modeling

There are several aspects in building the environment to which the body is exposed. Contact planes and ellipsoids are used to represent important geometric objects with which the body may interact. Harness belts, airbag systems, and personal flotation devices offer different restraint systems for the body. A predefined force or torque on the body can also be modeled.

2.3.1 Modeling the Environment Using Contact Planes

The contact planes are parallelograms which do not have any inertial properties, but which provide contact surfaces used to define the environment configuration. The interaction between the body and surrounding environment can be provided by contact forces between segments and contact planes.

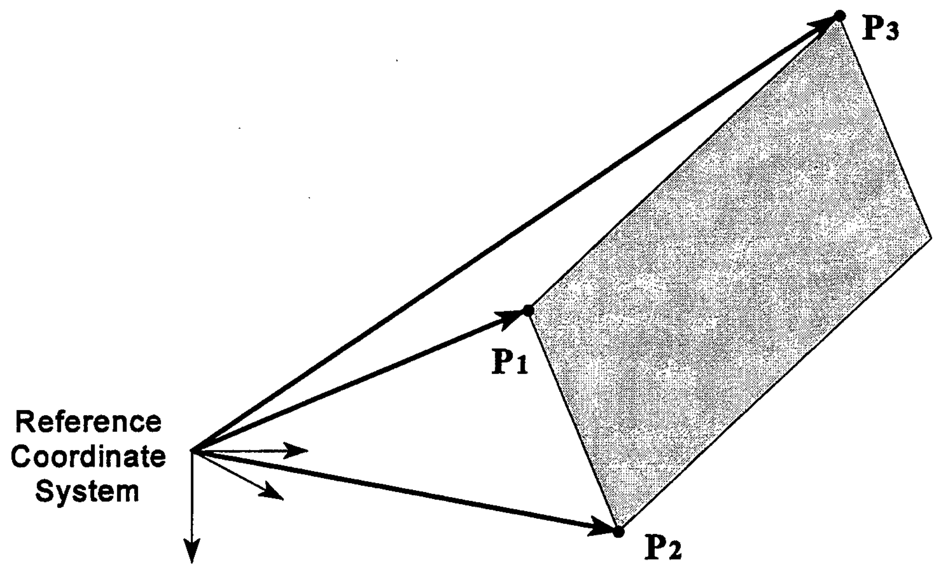

Figure 13. Plane Definition

In the ATB Model, a set of D.2 cards is used to define the contact planes. A plane is represented by the coordinates of its three corner points, P_1, P_2, and P_3 shown in Figure 13. These coordinates are given in the reference system of the segment, vehicle segment, or the ground (inertial segment) to which the plane is attached. The segment to which the plane is attached is specified in the F.1 cards. See Section 2.4 for further explanation. The order in which these points are listed defines the positive side of the plane. If the order is P_1, P_2, and P_3, then the force generated by the plane contact will be in the direction of the vector produced by the cross-product $P_1P_2 \times P_1P_3$, as shown in Figure 14. Users can refer to the D.2 cards in *example.ain* for an example of modeling a seat using contact planes.

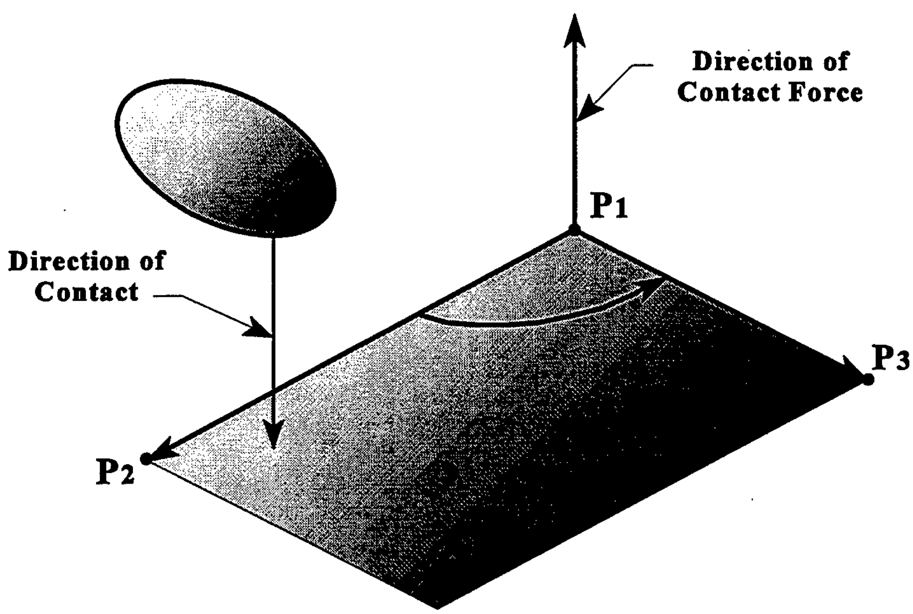

Figure 14. Positive Side of Plane

The maximum number of contact planes is **MAXPLN**. Though a user can use as many planes as possible to model the environment, the number of plane contacts can affect the computation time.

2.3.2 Additional Contact (Hyper)Ellipsoids

In addition to the ellipsoids defined with the body segments, the ATB Model has an option to attach contact (hyper)ellipsoids to body segments, vehicle segments or the ground (inertial) segment. The (hyper)ellipsoids have no mass or moments of inertia and hence no dynamic response. They are rigidly attached to a segment at a point and with an orientation specified with respect to the segment local reference coordinate system, as shown in Figure 15. As with the planes, the segment to which the (hyper)ellipsoid is attached is chosen on the F.1 or F.3 cards. See Section 2.4. The contact (hyper)ellipsoid coordinate system is formed by the three orthogonal semi-axes of the (hyper)ellipsoid, with the coordinate system's origin at the geometric center of the (hyper)ellipsoid. A normal contact ellipsoid has its power values, m, n, and p, equal to 2. An ellipsoid with its powers greater than 2 is called a hyperellipsoid. The function describing a (hyper)ellipsoid is $(x/a)^m + (y/b)^n + (z/c)^p = 1$. As the powers increase, the shape of the hyperellipsoid becomes more square. An example of using contact hyperellipsoids is the modeling of a pickup truck's squared exterior shape, as shown in Figure 4. Like the planes, the (hyper)ellipsoids are for contact purposes only.

The location of the contact (hyper)ellipsoid is specified with an offset vector which starts at the origin of the segment's local reference coordinate system and ends at the point where the center of the contact (hyper)ellipsoid is to be attached. The orientation of the contact (hyper)ellipsoid is specified by rotation angles with respect to the local segment reference system. If no rotation angles are specified for the contact (hyper)ellipsoid, the X, Y, and Z semi-axes of the contact (hyper)ellipsoid will coincide with the X, Y, and Z axes of the local reference system of the segment.

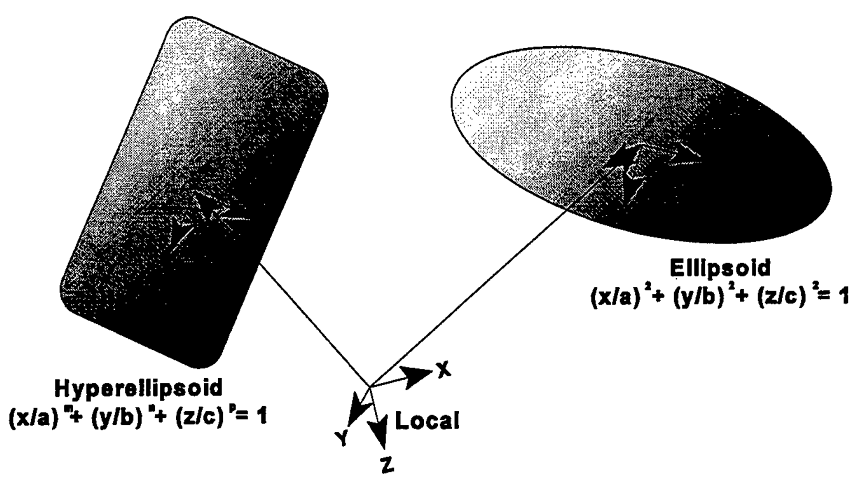

Figure 15. Additional (Hyper)Ellipsoids

Contact (hyper)ellipsoids can be used for (hyper)ellipsoid/(hyper)ellipsoid contacts and (hyper) ellipsoid/plane contacts, but only normal ellipsoids can be used for belt/ellipsoid contacts, harness belt/ellipsoid contacts or airbag/ellipsoid contacts (where the airbag is a special type of contact ellipsoid). More than one contact (hyper)ellipsoid can be attached to one (body, vehicle, or ground) segment.

2.3.3 Belt Restraint Systems

The ATB Model provides two options for modeling of belt restraint systems: simple belt and harness belt systems. In a simple belt system, each restraint belt is assumed to lie in a plane defined by two anchor points attached to a segment (usually the vehicle) and by a fixed point on a contact ellipsoid rigidly attached to some other segment (see Figure 16). Therefore, the belt is restricted to pass around a single segment. Although several simple belts may be used in an application, they cannot interact with each other. The dynamic properties of the simple belt are defined by initial slack, a force-strain function, and friction of the contact between the belt and the segment's ellipsoid. However, the friction is limited to either zero or infinite. A strain-rate-dependent function is not allowed for the simple belt. The main limitation of the simple belt model is that the point at which the belt contacts a segment is fixed to the segment and moves with it. The simple belt system is modeled by a set of D.3 and F.2 cards in input files.

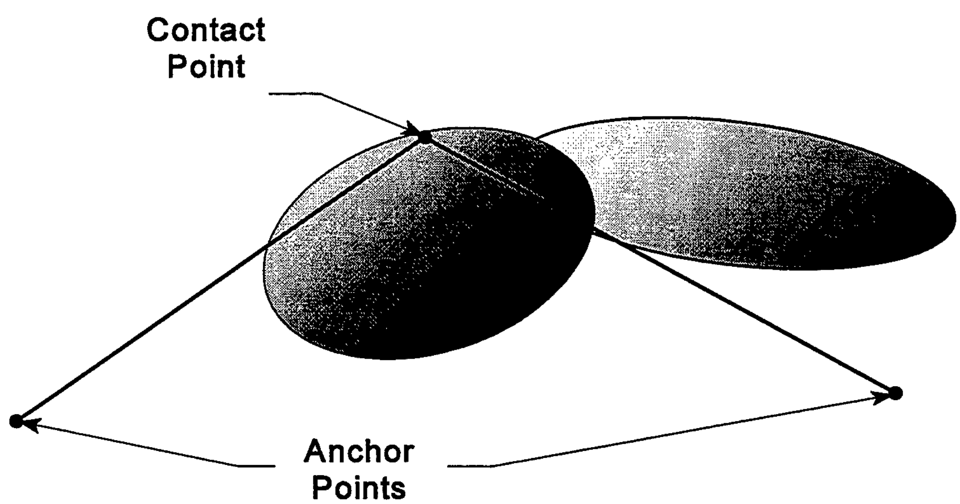

Figure 16. Simple Belt

The harness belt model overcomes some of the simple belt's limitations by allowing interactive belts that can slip over multiple segments. A harness consists of one or several belts. Each belt is formed by a set of straight line segments connecting prescribed reference points, shown in Figure 17. Endpoints of the belt may be anchor points or junction/tie points where several belts may join together. In *example.ain*, the set of F.8 cards models a harness system of four belts: a conventional double shoulder strap and a negative G strap tied together at the middle point of a lap belt.

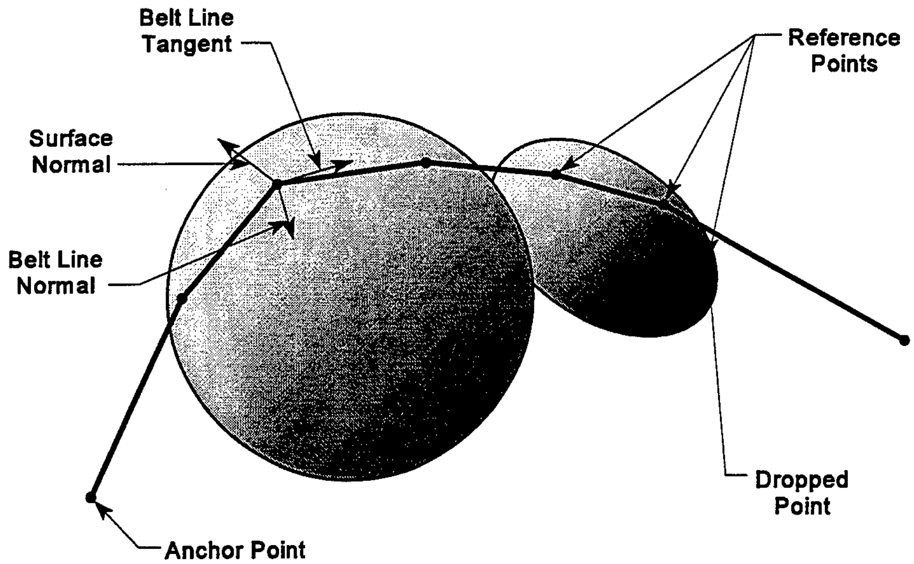

Figure 17. Harness Belt

The harness belt reference points are points of contact between the belts and contact ellipsoids. Their X, Y, and Z coordinates in the contact ellipsoid reference systems are given in Card F.8.d1 to determine their location on the contact ellipsoids' surfaces. These coordinates are the only ATB input data specified in terms of the contact ellipsoid coordinate systems. The supplied values are adjusted by the program to lie on the ellipsoid surface. Additional contact ellipsoids can be attached to a segment to better model the surface of the body. For example, in modeling the shoulder belt of a three-point harness shown in Figure 18, an additional contact ellipsoid with reference points is attached to the upper left portion of the upper torso to represent the belt layout on a human shoulder. It should be pointed out that hyperellipsoids cannot contact harness belts.

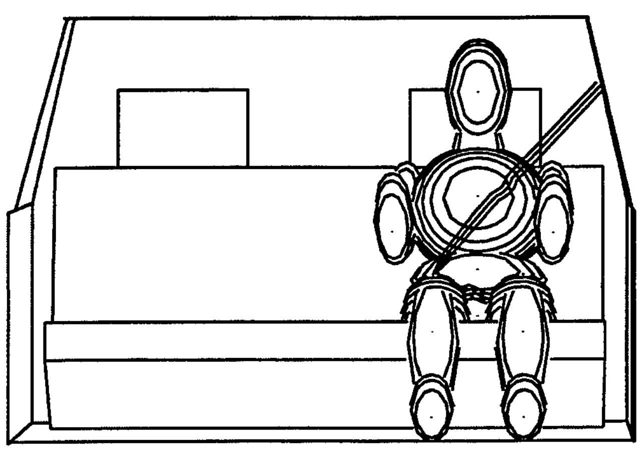
Figure 18. A Three Anchor Point Belt System

Depending upon the layout of the belt during each time step, some reference points may be "dropped" from the calculation of the belt trajectory and forces. A surface normal is used to determine whether a reference point will be included in the calculations. As shown in Figure 17, the surface normal is an outward normal vector to the surface of the ellipsoid at the reference point. If the net belt force on the ellipsoid at this reference point has a positive component along this normal, the point will be ignored in computing the belt forces. These dropped points may be picked up at a later time. In addition, if no ellipsoid is specified for a reference point, this point will always be used in the calculations. The user can find those reference points being dropped and picked up at any particular time step by checking the primary output file **.aou*, which is *example.aou* in the example case. A detailed description of the belt algorithms is given in Reference 3.

For a harness belt, you are required to define a strain or strain-rate-dependent force function for computing belt forces. If the belt's reference points are allowed to penetrate into the surface of the ellipsoids, force-deflection functions are also needed to describe these penetrations. These functions are assigned to each reference point in Cards F.8.d. If no force-deflection functions are provided, the ATB Model assumes the surface is rigid and no perturbations of the reference points normal to the surface are allowed. Furthermore, users can specify initial slack where a negative value indicates a pre-tightened belt.

A reference point can move tangential to the ellipsoid surface, both along and normal to the belt line. Friction coefficients between the belt and each ellipsoid can be defined in order to control the belt movement on the surface. Once the belt contact ceases at a reference point, the reference point will remain at its last belt contact position on the surface, until it has a negative normal force and is picked up again. If the belt separates completely from an ellipsoid and contacts it again later, the belt may not be able to pick up any reference points if the ellipsoid has rotated significantly. In that case, the belt may cut through the ellipsoid without producing any resistance forces. Therefore, in a simulation involving complex body motion, some additional reference points, such as the dropped point in Figure 17, may need to be defined in the input file. These will be used solely for later contacts. Care must be taken to make sure these points will not be picked up at the beginning of the simulation in order to avoid an unrealistic belt configuration.

2.3.4 Simple Airbag Restraint System

The simple airbag model is a non-stretchable bag of ellipsoidal shape which interacts with contact ellipsoids attached to selected segments of the bodies or the vehicle. Figure 19 gives a complete picture of the airbag model. Those contact ellipsoids attached to the vehicle for holding up or confining the airbag are called reaction panels. At least one such contact ellipsoid, called the primary reaction panel, is required in modeling the airbag. A point on this panel is specified as the deployment point from which the bag deploys. At the beginning of the simulation, the bag is assumed to have zero volume and be located at the deployment point. After a specified time, the bag is inflated by using the gas dynamic relations for the choked flow of gas through a nozzle. The gas source is a high pressure tank of constant volume. The total amount of gas coming through the nozzle is the volume of gas in the fully inflated bag, at atmospheric pressure.

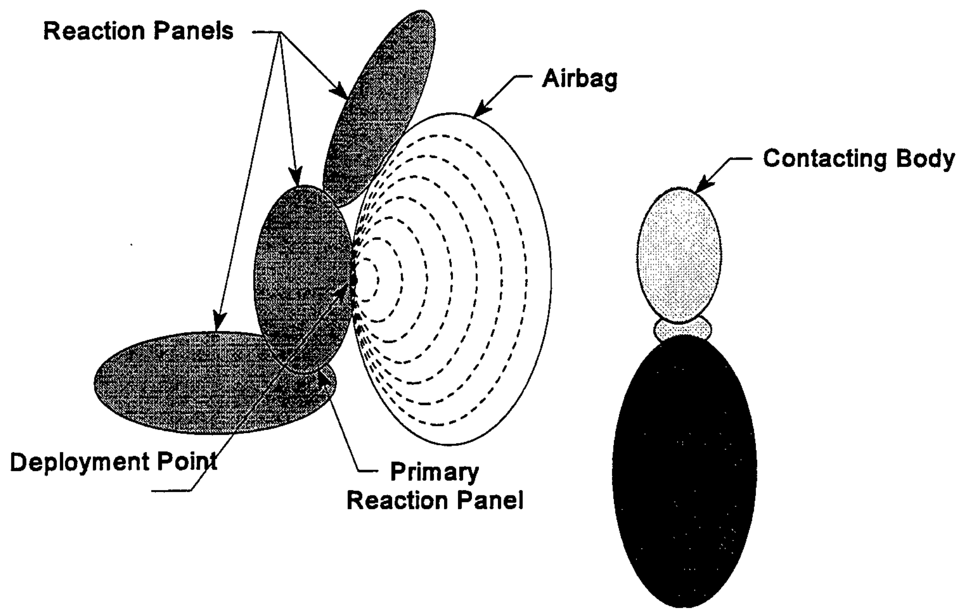

Figure 19. Airbag

During inflation, the size of the bag is determined by scaling the semi-axes of the ellipsoid by the cube root of the volume. The center of the bag lies on a vector which has one end at the deployment point and is parallel to the X axis of the primary reaction panel but in the negative X direction. The center's distance from the deployment point is equal to the X semi-axis of the sealed bag at that instant of time. The set of ellipsoids drawn by dashed lines in Figure 19 illustrates this inflation process.

When the bag is fully inflated, it is assigned mass properties and moves dynamically like any other mass system. Until it is fully inflated, the orientation of the bag with respect to the vehicle is held constant and equal to its initial orientation. The dynamic motion of the bag is updated by the program integrator. An artificial spring force is applied at the end of the positive X axis of the bag and is exterior to the primary reaction panel. This holds the bag to the panel.

During the inflation, the bag is assumed to be at atmospheric pressure and hence no contact forces are produced until the sum of the instantaneous volume of the bag and the volume of intersection due to contacts with other segments reaches the geometric volume of the fully inflated bag. Once the bag is fully inflated, any additional gas from the gas tank or an increase in the volume of intersection will cause the pressure in the bag to increase and thus produce contact forces on any contact ellipsoids intersecting the bag. Each intersection of a contact ellipsoid and the bag is treated separately by the ATB program, which computes the decrease in the volume of the bag, the effective area of the contact and the force and torque per unit pressure. After all the contacts have been considered, the total decrease in volume is used to compute the pressure of the gas in the bag and then the forces and torques are applied to the various ellipsoids at their maximum penetration point into the bag.

A set of D.4 cards are used in the ATB Model to define airbag parameters. A detailed airbag formulation can be found in Reference 5.

2.3.5 Applied Force and Torque

The ATB model has the capability to apply time-dependent forces and torques to body segments, as shown in Figure 20. A force/torque coordinate system is defined such that a positive force is applied in the positive X direction of the force/torque coordinate system and a positive torque is applied about the positive X axis of the force/torque coordinate system using the right-hand rule. The origin and orientation (rotation) of the force/torque coordinate systems are specified with respect to the local reference coordinate system of the segment to which the force/torque is to be applied. Cards D.9 specify these parameters for the ATB simulation.

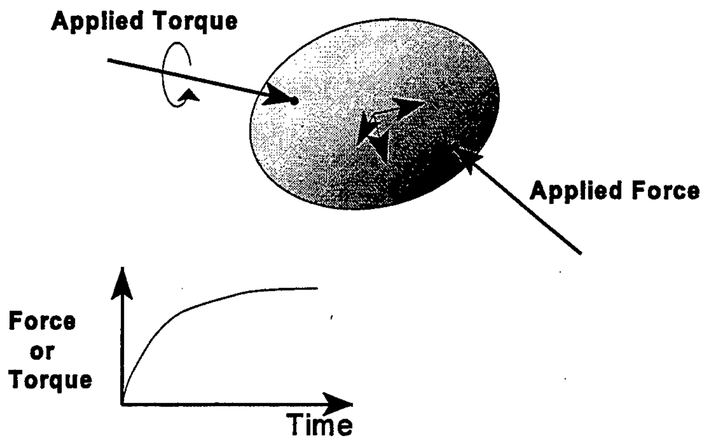

Figure 20. Applied Forces

2.3.6 Wind Force Modeling

The wind force option was developed to tackle the case where pilot ejection is simulated. It applies pressure type forces, such as aerodynamic forces, to any segments which penetrate a boundary plane, called the wind plane, as shown in Figure 21. Once a segment's ellipsoid penetrates the wind plane, an estimate of the projected area normal to the wind pressure is made, and the force and torque are computed and applied to the segment. For partial penetration, the force is applied at the center of the intersection ellipse between the ellipsoid and wind plane. At full penetration, the force is applied at the center of the ellipsoid.

The wind plane is defined using the D.2 card, the same as other regular planes. The user must state explicitly in the F.7.a card which segments are desired for wind force calculation. Then, the F.7.b card associates these segments with the wind plane and wind pressure functions, as well as drag coefficients defined in Card E.6. There are two types of wind pressure functions. The first is a time-dependent wind pressure function which gives the X, Y and Z components of the wind pressure vector in the reference coordinate system with respect to time. The second type computes the wind pressure vector as a function of the relative velocity of a segment. A time-dependent drag coefficient function can also

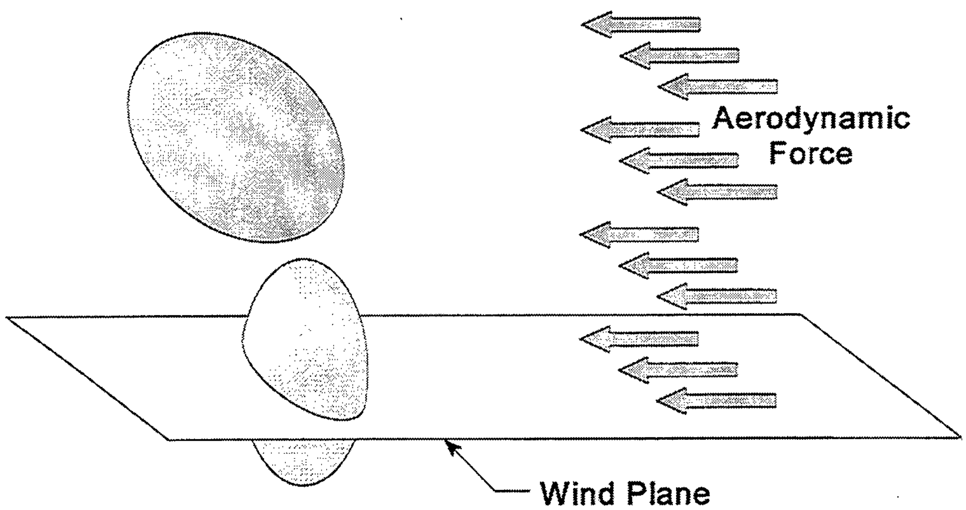

Figure 21. Wind Forces

be defined in Card E.6. The wind force acting on a segment will equal the wind pressure function value multiplied by the drag coefficient. If no drag coefficient is defined, 1.0 will be used. Additionally, a method of calculating the wetted area to account for segments blocking the wind is also available. A detailed formulation of the wind force modeling method can be found in References 3 and 10.

2.3.7 Water Force Simulation Environment Modeling

The water force simulation is used to predict gross human or dummy body response due to water forces with the body fully or partially submerged and with or without attached PFDs (Personal Floatation Devices). Modeling of water forces requires representation of the water surface and PFDs. Figure 22 shows a human subject wearing PFDs floating above the water surface. The subject is partially submerged.

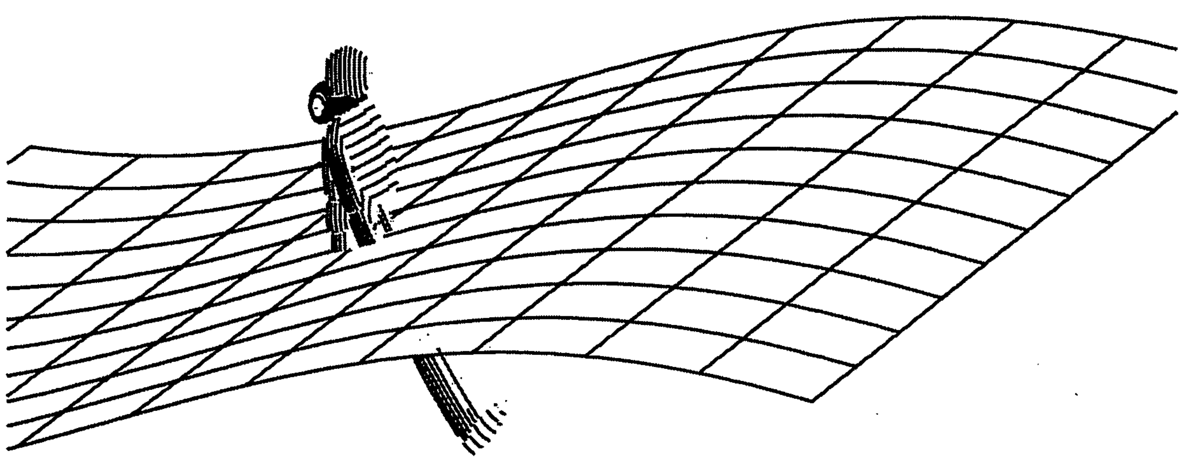
Figure 22. Water Force Simulation of a Human Subject with PFDs

A representation of the water surface consists of the mean water surface and waves forming the free-water surface. The mean water surface is defined as the X-Y plane of a Cartesian coordinate system called the water frame. The water frame's origin and orientation are given with respect to the inertial coordinate system, and its Z axis points downwards into the water. Figure 23 depicts this relationship. Therefore, the mean water surface is fixed in space and time and used as the location of the water surface. To have both spatial and time variations for the actual free-water surface, waves are defined and superimposed on the mean water surface. There are two representations of the free-water surface available in the ATB Model. One uses a set of regular waves which are two-dimensional, sinusoidal waves. The user inputs wave length, amplitude and phase angle, etc., to define these waves. The ATB Model allows the user to utilize up to ten regular waves to describe the free-water surface. The program will superimpose the components due to each wave in computing the free-water surface. Another option allows the user to represent the free-water surface by a single regular wave based on the Pierson-Markovitz spectrum for fully-developed ocean waves. The user only needs to supply a wind velocity at a standard height of 63.98 ft above the free surface. The ATB Model will compute the rest of the wave parameters.

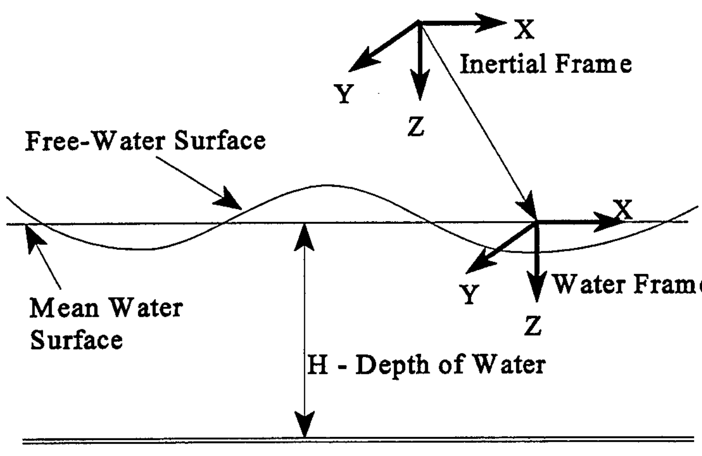

Figure 23. Water Surface Model

For the portion of the body submerged in water, the ATB Model computes the water forces and torques acting on it. The water forces include the effects of hydrostatic pressure, wave excitation, added mass, drag and lift. The hydrostatic effects arise as a result of hydrostatic fluid pressure acting on a body. The wave excitation effects are due to the dynamic pressure exerted by the waves. The added mass effects result from a volume of surrounding fluid accelerated with a body. The parameters describing these effects are supplied in the ATB input file by a set of corresponding coefficients.

The ATB Model allows the user to approximate each PFD by up to five rigid ellipsoids. These ellipsoids are called PFD ellipsoids. Each PFD ellipsoid is modeled as if it is rigidly connected to a body segment and has similar characteristics as a regular contact ellipsoid. The semi-axes, ellipsoid center offset, and orientation of the ellipsoid coordinate system are defined with respect to the local

reference system of the segment to which it is attached. The ATB Model allows modeling of up to five PFDs.

In an ATB input file, a set of F.9 cards are used to define the water surface, water force coefficients, PFDs, and other water force simulation parameters. For a detailed theoretical formulation of the water force model, Reference 12 is recommended.

2.4 Contact Definitions

The interactions between the body and the environment are expressed in terms of the contacts which happen between the body's segments and the elements representing the environment. There are seven major types of contacts used in the ATB Model:

1. Plane/ellipsoid
2. Ellipsoid/ellipsoid
3. Segment/belt
4. Segment/airbag
5. Segment/water
6. Segment/harness belt
7. Segment/spring-damper

The last five types of contacts have been described in previous sections. This section focuses on the contact models used most frequently (plane/ellipsoid and ellipsoid/ellipsoid contacts) and the functions used by all of the contact models.

2.4.1 Plane/Ellipsoid and Ellipsoid/Ellipsoid Contact

The outer shape of each segment is defined by the contact ellipsoid attached to the segment. Most segments have only one contact ellipsoid while some segments may have several contact ellipsoids, hyperellipsoids, or planes. Since the vehicle and ground are also segments, they may have contact (hyper)ellipsoids attached to them, as well as planes. Therefore, a contact with the segment is in effect a contact with the segment's contact (hyper)ellipsoids. Referring to *example.ain*, the sets of Cards F.1 and Cards F.3 define the plane/ellipsoid and ellipsoid/ellipsoid contacts, respectively, in this way. The user can define contacts for all of the combinations between planes and ellipsoids, and ellipsoids and ellipsoids. However, it will save computational time to define only the contacts which are likely to occur. Several test runs can be used to refine and reduce the contact definitions.

For a plane/ellipsoid contact, the contact forces consist of a normal force and a friction force computed by the ATB Model's force-deflection routines. When an ellipsoid contacts with a plane, it penetrates the plane. The ATB Model finds the maximum penetration of the given ellipsoid into the given plane at each time step, as shown in Figure 24. This penetration is the deflection meant by the ATB Model. The contact forces corresponding to this deflection are calculated from the contact property functions used in Cards F.3 for defining this contact. The computed forces are applied at a point along the line joining the point of maximum penetration and the center of the intersection area. The ATB Model has the capabilities to conduct an edge effect test, handle complete penetration by the ellipsoid, and deal with infinite planes. The edge effect test handles the situation where only part of the intersecting ellipse is within the plane boundaries. The infinite plane option allows the user to assume an infinite plane; therefore, no boundary test is made. It should be noted that the plane has a positive side and a negative side, as described earlier. The contact force vector has the same direction as the plane normal, directed out of the positive side. If an ellipsoid comes into contact from the negative side of the plane, it results in a sudden large contact force pushing the ellipsoid through the positive side of the plane.

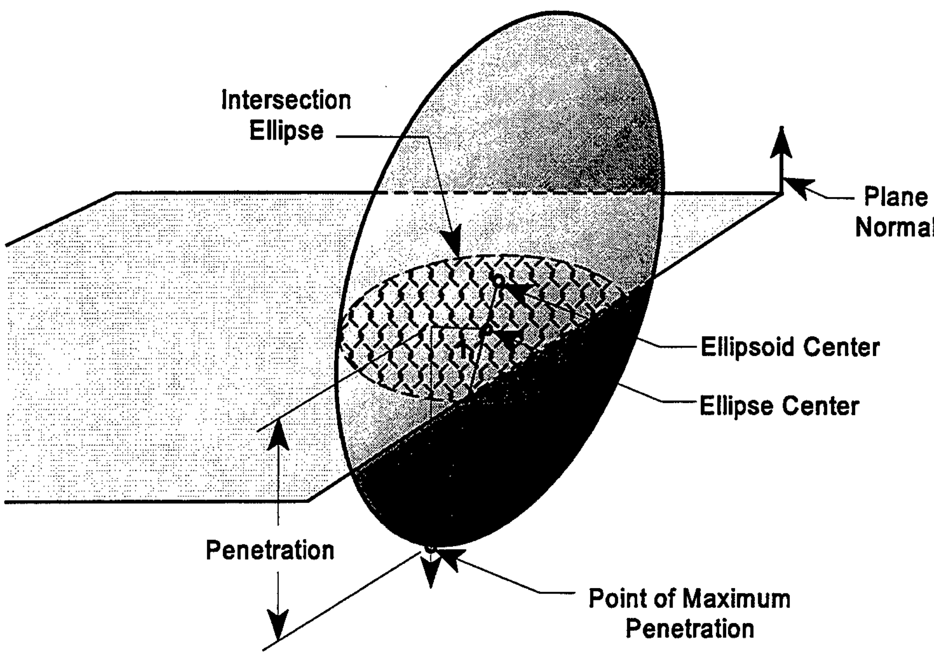

Figure 24. Plane/Ellipsoid Contact

Similar to plane/ellipsoid contacts, the contact forces generated from an ellipsoid/ellipsoid contact are functions of the penetration value of one ellipsoid into another, as shown in Figure 25. The penetration value is decided by contracting both ellipsoids until a single point of contact is achieved. Figure 25 shows an exterior contact in which one ellipsoid approaches another from the exterior. The ATB Model also allows an interior contact in which ellipsoid A contacts ellipsoid B at B's interior surface,

though this is a rarely used option. For interior contacts, ellipsoid A must be completely inside ellipsoid B before contact.

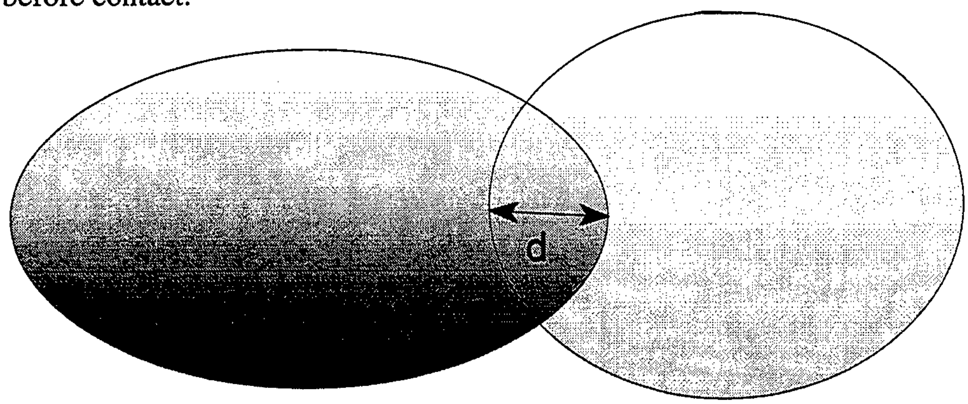

Figure 25. Ellipsoid-Ellipsoid Contact

It should be pointed out that the contact properties are mutual characteristics associated with each specific paired contact. For example, if test data are available, the contact properties between the head ellipsoid and dashboard plane should be different from those between the upper torso ellipsoid and dashboard plane.

2.4.2 Functions of Contact Properties

For many of the contact definitions, a set of function numbers are used to define the contact properties for that particular contact. Each individual contact function is defined in Cards E.1 through E.4. Contact properties are described by a combination of individual functions. In most cases there are two ways to specify this combination.

The first method uses five functions in combination to describe the contact properties. They are: the base force-deflection function, the inertial spike function, the energy absorption function, the permanent deflection function, and the friction coefficient function. The function numbers of these five functions are used in the contact definition. Figure 26 depicts this concept. These are all functions of deflection or constant values. The base force-deflection function is used to determine the normal contact force. The inertial spike function is used to model the inertial loading that might take place when a plane/ellipsoid contact is initiated. The definition of each inertial spike function includes an abscissa value D3 in Card E.2 for the function such that if unloading occurs after deflection exceeds D3, the inertial spike is to be ignored. An example using inertial spike might be the contact between the head and the car's windshield, in which case an extra inertial loading is needed before the windshield is broken. The energy absorption function, also called the R factor, ranges from 0 to 1 and is used to specify the amount of energy recovered at the end of unloading. The permanent deflection function, also called the G factor, ranges from 0 to 1 and is used to model permanent deformation X_{PERM} due to the contact force. For the subsequent contacts, loading will not start until X_{PERM}. Both the R and G factors are used to approximate the effects of hysteresis, defining the unloading and reloading curve calculations. The unloading curve is a quadratic polynomial from the base curve to

X_{PERM}. The reloading curve is a cubic polynomial from the point of reloading to the base curve at X_{MAX}. The friction coefficient function is used to compute the contact friction force which is proportional to the normal force and in the opposite direction of the tangential velocity. In summary, this method establishes a contact behavior as first loading along the base force-deflection curve plus the inertial spike (if it exists), then proceeding down an unloading curve between X_{PERM} and X_{MAX} after the deflection reaches X_{MAX}. In *example.ain*, the ellipsoid/ellipsoid contact definitions in Cards F.3 use this method.

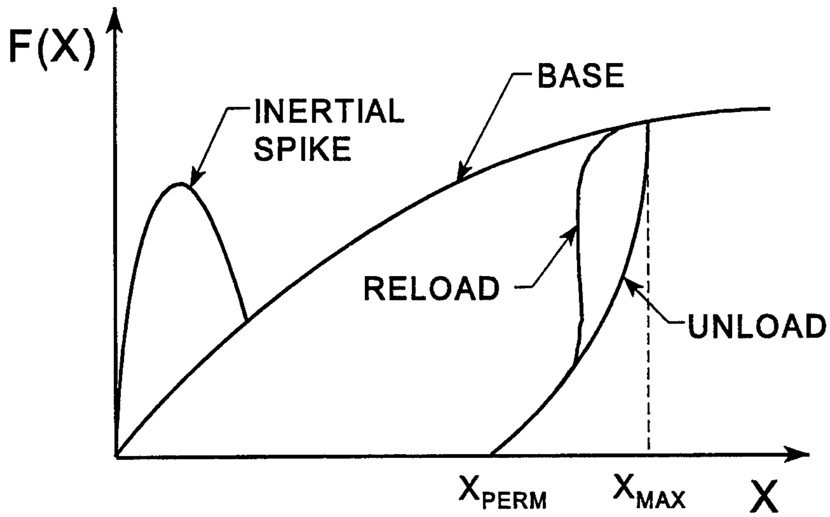

Figure 26. Functions

The second method describes the contact properties using a rate-dependent function, F(x, x'), where x and x' are the deflection and deflection rate, respectively. A combination of four individual functions are used to construct F as shown in Figure 27. F_1, F_2, F_3, and F_4 do not have to have any special physical meanings and may be used as pure mathematical expressions for the purpose of constructing F. The function numbers of these four individual functions plus the friction coefficient function are used in the contact definition. This option is invoked by setting the function numbers of F_2, F_3, and F_4 in Cards F.1 or F.3 all to be negative. In *example.ain*, the block of F.1 cards defining plane/ellipsoid contacts uses this method.

$F=F_1(x') + F_2(x')F_3(x') + F_4(x')$

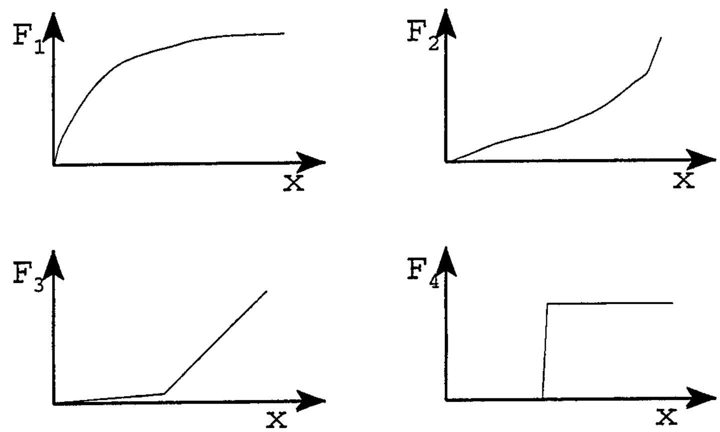

Figure 27. Rate-Dependent Functions

Each individual function used in the above methods can be defined using tabular data and/or a polynomial expression of up to the fifth-degree in Cards E.1 to E.4. Constant value functions are allowed. For example, in *example.ain*, function 14 is a constant function specifying the friction coefficient; function 13 is a tabular function defining a base force-deflection function for contact between ellipsoids and stiff surfaces; function 31 is a linear (first-order polynomial) function defining the force-strain relation for harness belts. Furthermore, each individual function may be subdivided into two adjacent functions f_1 and f_2, where the upper abscissa value of f_1 will be the lower abscissa value of f_2, as indicated in Figure 28. The input formats of f_1 and f_2 depend on the signs of D0, D1, and D2 on the E.2 cards.

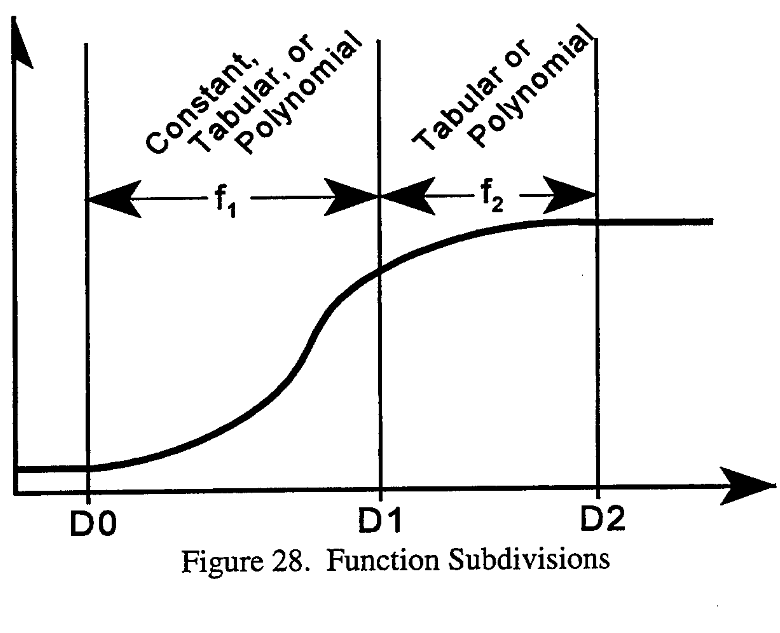

Figure 28. Function Subdivisions

2.5 Prescribed Motion and Initial Conditions

2.5.1 Vehicle Definition and Prescribed Motion

A vehicle in the ATB Model is a massless segment with prescribed motion. Unlike the body segments described by B cards, vehicle segments are automatically created by C cards where its prescribed motion is defined. Vehicle segments are primarily used to offer a reference coordinate system (see section 2.2.2) and establish an acceleration time history for the environment in which the bodies reside. Therefore, it usually has contact planes and/or additional ellipsoids defined with respect to it (see section 2.3). For example, in *example.ain*, the sled is a vehicle segment with a deceleration sequence defined in the C.3 cards. The seat panels are defined in the vehicle coordinate system, i.e., with respect to the sled.

The ATB Model allows up to six prescribed motions to be defined. Each prescribed motion has its own set of C cards, with the primary vehicle being defined by the last set of C cards in the input file. The remaining prescribed motions not associated with a segment defined in the B cards are called secondary vehicles. The numbering convention for segments in the ATB Model is, from low to high, the body segments followed by the secondary vehicles, the primary vehicle, the airbags if any, and then the inertial system segment, which is the ground segment by default. In *example.ain*, the sled is the only vehicle; therefore it is also a primary vehicle. The secondary vehicles are very useful in modeling objects which move within the primary vehicle. For example, in a pickup truck simulation with roof crush as shown in Figure 29, the primary vehicle is the pickup truck and the roof is modeled as a secondary vehicle. Most planes are defined with respect to the primary vehicle, which has its segment local reference system at the point described by the pickup truck's prescribed motion. However, the roof and side rails are attached and defined in the local reference system of the secondary vehicle, which has the time history of roof crush movement as the prescribed motion. The roof crush movement in turn may be defined with respect to the primary vehicle or the inertial reference system.

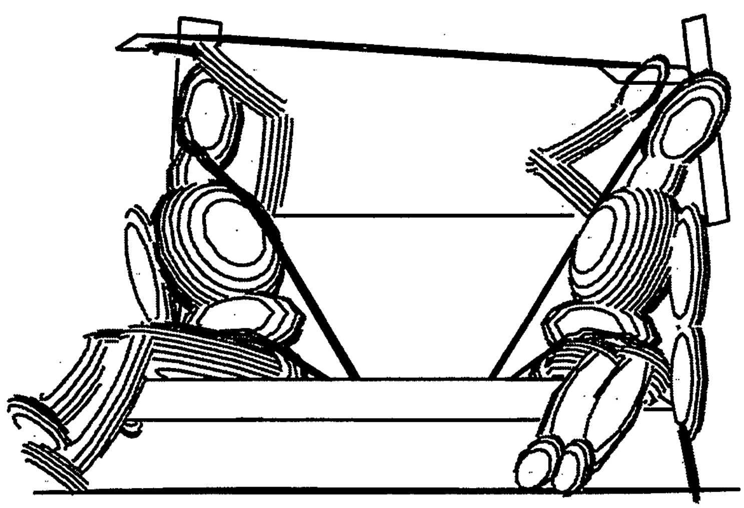

Figure 29. Pickup Truck Rollover with Roof Crush

The ATB Model requires at least one vehicle, the primary vehicle, to be defined in every simulation. If there is no object suitable for vehicle definition, a motionless dummy vehicle can be defined as the primary vehicle for the simulation. The water force simulation in Section 2.3.7 is such a case.

A body segment defined in the B cards may also be given prescribed motion if the segment is a reference segment. Similar to a vehicle, the body segment's prescribed motion is defined by a set of C cards.

Each prescribed motion time history in the C cards is specified relative to a reference system. The reference system can be that of another prescribed motion segment, or the default ground (inertial) segment. Four options are available for specifying the motion data. They are:

Option 1: Half sine wave deceleration pulse
Option 2: Tabular unidirectional deceleration
Option 3: Six-degree-of-freedom deceleration
Option 4: Spline fit position, velocity, or deceleration data.

Option 1, as depicted by Figure 30, is the simplest way to define vehicle motion. The half sine wave in the top graph is obtained by inputting an initial velocity and time duration, VTIME, of the pulse. The magnitude of the deceleration is automatically calculated so that the final velocity is zero. The orientation of the deceleration vector is given by azimuth and elevation angles. A set of X, Y, Z coordinates is used to specify the vehicle's initial position in the reference system. This option is often used to approximate the vehicle motion when detailed motion data are unavailable. *Example.ain* uses this option. Option 2 is similar to option 1 except that the half sine wave is replaced by a table of unidirectional deceleration data supplied at a fixed time interval, ATD, as in the bottom graph.

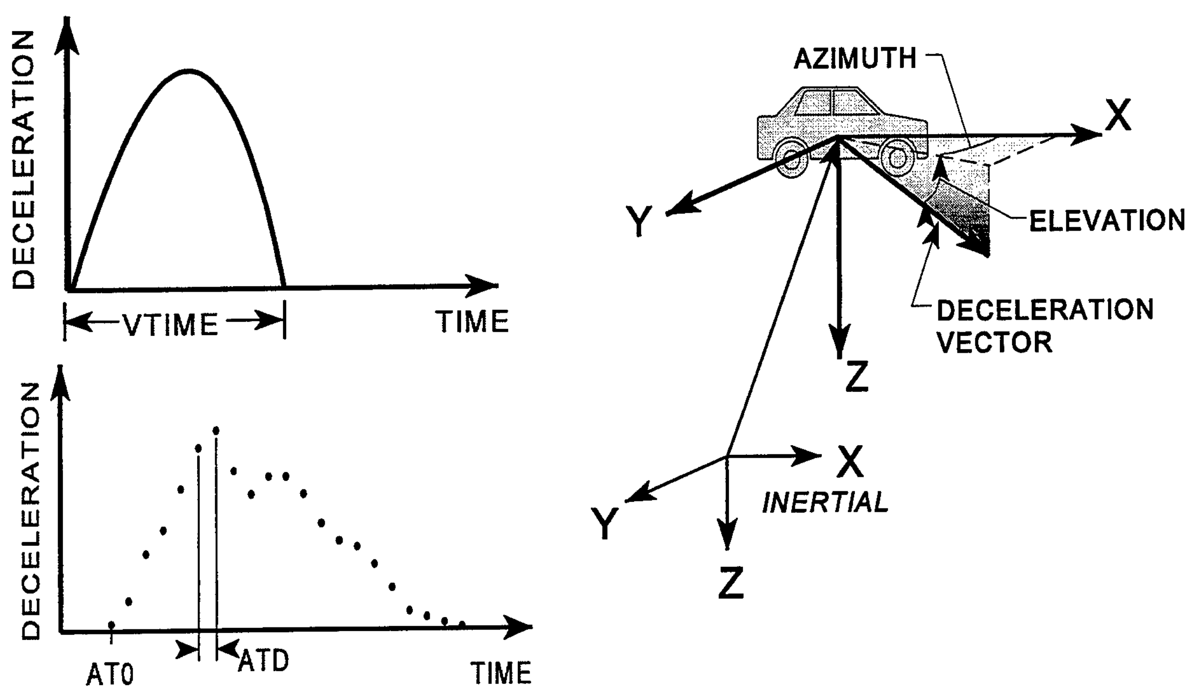

Figure 30. Prescribed Motion Options 1 and 2

To define more complex three-dimensional vehicle motion, option 4 is recommended for its spline fit capability. Figure 31 demonstrates the input involved in this option. A table of data of the vehicle's position, velocity, or acceleration vs. time is used to generate spline fit functions. If the table is a position table, the position vector (X_x, X_y, X_z) and the vehicle's yaw, pitch, and roll (θ_z,θ_y, θ_x) are input. If it is a velocity table, the velocity vector (v_x, v_y, v_z) and angular velocity vector (ω_x, ω_y, ω_z) are input. An acceleration table uses the deceleration vector (a_x, a_y, a_z) and angular acceleration vector (α_x, α_y, α_z). The ATB Model will spline fit these data using polynomials and then compute the vehicle motion at a fixed time interval, set by the user. In spline fitting angular positions, the angle values will be transformed into quaternions and the four quaternion components are each spline fit independently. The yaw, pitch, and roll are then computed from the quaternions. Option 3 is similar to option 4 except that only decelerations are allowed and the data must be supplied at even time points. The decelerations are used directly by the program and spline fitting is not required.

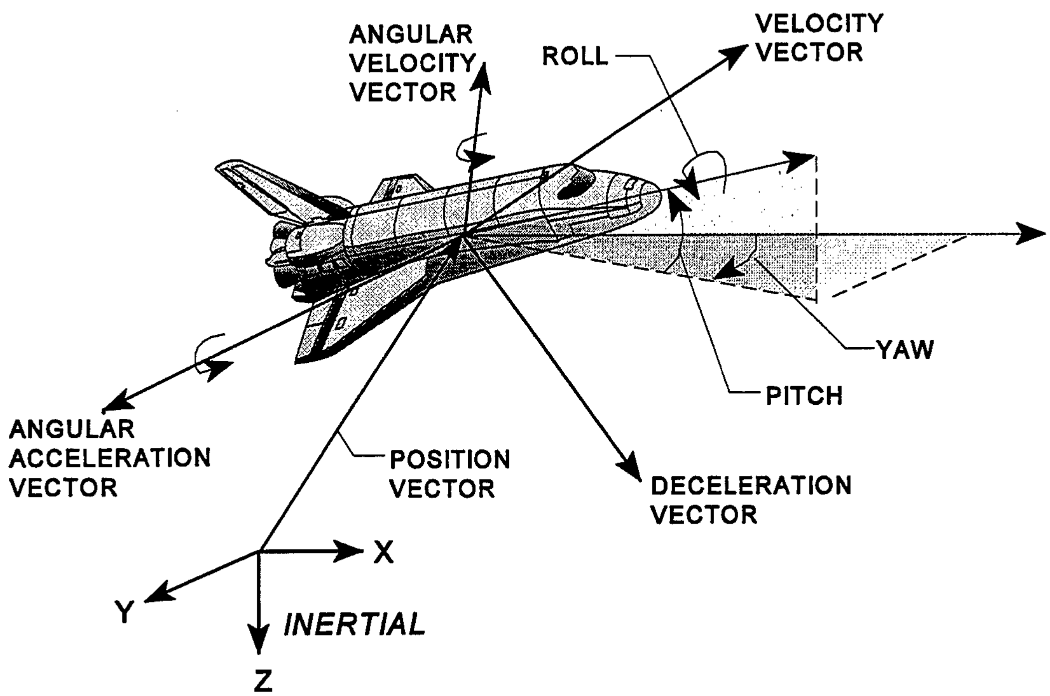

Figure 31. Prescribed Motion Option 4

2.5.2 Initial Positioning of Body

For body segments, the initial positions and velocities are defined by a set of G cards. First, a G.2 card is used to specify the initial velocity and CG position of each body's reference segment in a vehicle or ground (inertial) reference system. Initial segment velocities can be set equal to a vehicle's initial velocity. Once the reference segment is positioned, the initial yaw, pitch, roll, and angular velocities of all the body segments' local reference systems are specified by a set of G.3 cards. This in effect defines all the segments' initial conditions since the body is modeled in a chain structure. Therefore, in the process of setting up a body's initial conditions, the positioning of the reference segment in the

G.2 cards defines the whole body's location and the specifying of angles and angular velocities in the G.3 cards defines the body's posture. These initial orientations and velocities may be specified with respect to the ground, any vehicle, or any segment previously positioned. Figure 32 depicts this concept.

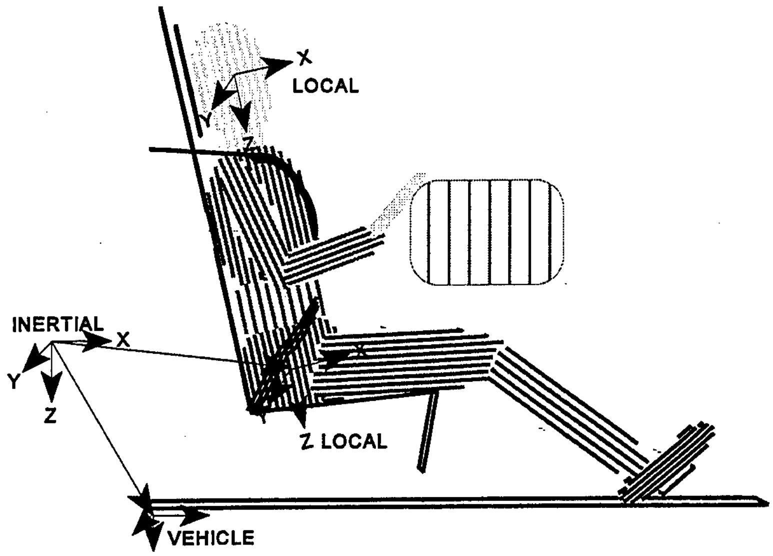

Figure 32. Initial Conditions

For a body free in space, the above process can be relatively straightforward; however, when the body is confined by the surrounding environment (for example, sitting on a seat), the process can become fairly involved. The reason for this is that the body must initially be in static equilibrium, and this equilibrium is achieved by balancing gravitational forces against contact forces. The latter are highly position-dependent and must be properly chosen to avoid large initial segment accelerations due to unbalanced forces and torques on the body. An iterative adjustment process is often used to achieve this objective. In adjusting the segment orientations, care should be taken that the joints are not positioned beyond their stops or inconsistent with their rotational constraints.

The iterative method requires that the simulation is executed to zero time. A tabular printout of all of the external forces and torques and resulting linear and angular accelerations is produced for time zero. Joint torques can also be checked for inconsistencies. Then the user adjusts the positions based on the contact forces and the initial linear and angular accelerations. This procedure usually requires several iterations to ensure that the body is in static equilibrium with its environment, which is determined by the absence of large accelerations for any of the body segments. Perfect equilibrium is generally not attainable for the seated or standing position; however, small initial accelerations are tolerable, especially for the angular accelerations which are usually difficult to balance, as long as they are much smaller than the accelerations induced by the dynamic environmental conditions under study.

For initially balancing seated human or dummy subjects, the following steps are suggested:

1. Start position.
   - Torso segments parallel with the seat back.
   - Legs rotated above the floor and pedals.
2. Adjust the lower torso position to balance more than 60% of the total body weight.
   - Rotate torso segments to contact seat back.
3. Rotate upper legs down to balance most of the body weight.
   - Check horizontal forces. The combined forces should be close to zero.
4. Rotate lower legs to fully balance weight with foot/floor contacts.

2.6 Dimension Units, Gravity, and Time Control of the ATB Program

Before any body or vehicle data can be considered for input to the model, the user must decide the units of measurement to be used and the gravity direction, relative to the inertial system.

2.6.1 Selecting Dimensional Units

The units of measurement for the input data (i.e., pounds/inches/seconds or Newtons/meters/seconds) must be chosen. The choice is arbitrary and there is no default, but once the selection is made, all input data must be in the same units. Choosing the units of measurement for the input data also automatically specifies the units for the output data. The units of measurement are selected by supplying the alphanumeric names of the abbreviations for the units of force (UNITM), distance (UNITL) and time (UNITT).

The units of measurement used in the ATB Input Description for illustrative purposes are pounds, inches, and seconds. These units were selected at the time of the initial development of the model when most available data were in these units. Although there are no official units, the format (field width and number of digits following the decimal) for various input and output items was established on the basis of the expected magnitude of these data for a simple car crash type simulation, assuming the pound, inch, and second measurement system. Hence it is possible that a different choice of units may result in data that, while numerically correct, may not fit in the specified input and output format.

Note that mass units are not required for input and output purposes, although they are assumed internally by the program. This is accomplished by supplying the weight of the body segments using the force units. The ATB program converts these input values to mass units by dividing these force units by the value of the acceleration due to gravity, which must be provided as input. Unfortunately, an inconsistency was introduced during the early development of the program for the principal moments of inertia input units. In retrospect, the units for the principal moments of inertia should have been weight (force) multiplied by distance squared, and the input values converted by the program by dividing by the acceleration due to gravity, as is done for the segment weights. As the input is now established, the required units for these principal moments of inertia are weight (force) multiplied by distance multiplied by time squared, which is equivalent to mass multiplied by distance squared. This

inconsistency has never been removed because its removal would invalidate many already established input files.

Finally, both the GEBOD and VIEW programs employ similar unit conventions as the ATB Model.

2.6.2 Specifying Gravity

Once the units of measurement have been selected, the user must define what is meant by the inertial coordinate system. As discussed earlier, the inertial coordinate system is the coordinate system to which all other coordinate systems are referred and it is within this system that Newton's laws hold. The inertial coordinate system of the model is assumed to be at rest, but is designated as a segment called the ground segment with its segment number given by **NGRND**. The inertial coordinate system is defined by specifying the gravity vector GRAVTY. Most whole-body simulations define the gravity vector GRAVTY as (**0**, **0**, **g**), to be aligned with the positive Z axis of the inertial coordinate system. **g** corresponds to the standard coefficient of gravity at the surface of the earth.

The gravity field defined by GRAVTY is assumed to be constant throughout space and time in the ATB Model and is applied to all segments that are given a nonzero weight. The magnitude of the vector GRAVTY is used to compute the masses of the segments from their supplied weights. If the user wants to simulate the motion of an object in a zero gravity field, such as a spacecraft in deep space, the gravity vector would be supplied as GRAVTY (**0**, **0**, **0**). The magnitude of this vector is obviously zero, so computation of the masses of the segments from their weights would not be possible using the magnitude of GRAVTY. To circumvent this problem, the user has the option of supplying G. G represents a factor by which the weights of the segments will be divided to yield a mass. If G is supplied as nonzero, the ATB program will use the value of G (rather than the magnitude of GRAVTY) to compute the masses of the segments and will apply the force vector, GRAVTY, to all segments with a nonzero mass. G must be nonzero when GRAVTY (**0**, **0**, **0**) is used.

2.6.3 Integration and Output Time Control

Time control parameters must be specified for each simulation. These parameters control the length (simulation time) of the run, the amount and format of the output, the tabular time histories, and operation of the program integrator. Although the program places no restrictions on these input parameters, a judicious choice of the parameters can improve computational efficiency and numerical stability. For the purpose of clarity, the following description will assume that UNITT, units of time, are seconds.

Figure 33 illustrates the time control mechanism. After all input and initialization are performed, time is advanced in overall steps of **DT** seconds. The optional output is provided at time zero and each integral multiple of **DT** seconds of simulation time. The total simulation time is **NSTEPS*DT** seconds where **NSTEPS** and **DT** are input parameters. The values of **NSTEPS** and **DT** should be chosen to provide the desired length of the simulation, and the amount and frequency of output data.

A secondary control of time is performed by the program integrator. Integrator steps are controlled by the supplied values for **HO**, **HMIN**, and **HMAX**. The integrator advances time in substeps of **H** seconds starting with **HO** and varying between **HMIN** and **HMAX**. **H** is halved when convergence of the integrator parameters is not achieved, but **H** is not permitted to become less than **HMIN**. If convergence is not attained with an **HMIN** time step, the simulation stops with a descriptive error message written to the *.aou* file. If the convergence criteria are satisfied for several integration steps, **H** is doubled. This can continue until the integration step reaches **HMAX**. **H** is also adjusted to provide an integrator time step at each integer multiple of **DT**, so that output data is available. For this reason, it is best that **DT** be an integer multiple of **HMAX** so that the **DT** time step will be executed in equal **HMAX** substeps during periods of stable activity. Also, since the value of **H** is permitted to double during these stable periods or be halved during unstable periods, the integrator will execute more efficiently if **HMAX** is a power of two multiple of **HMIN** and **HO**.

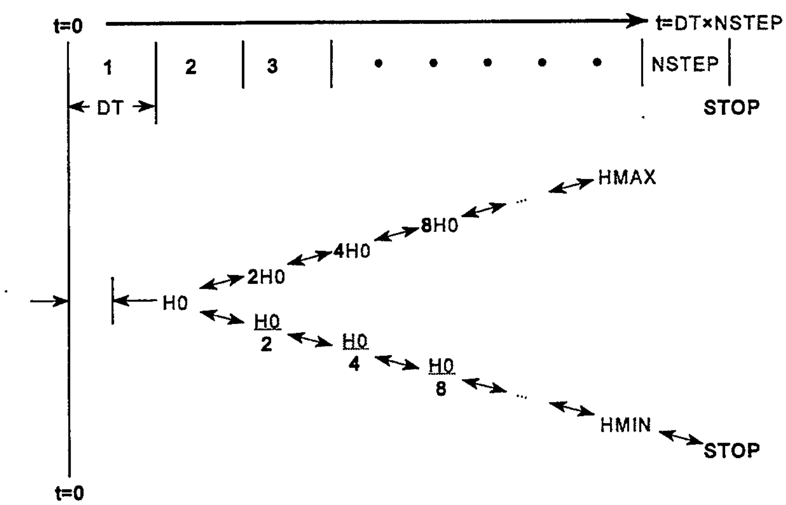

Figure 33. Time Step Definitions

It has been observed that suitable values for **HMAX** lie between one and five msec for most occupant and pedestrian simulations. Generally, values for **DT** of 0.002, 0.004, 0.010, or 0.020 seconds; for **HMAX** of 0.001 or 0.002 seconds; and for **HMIN** and **HO** of 0.000125 or 0.000250 seconds work satisfactorily. It is possible to execute the integrator in a "fixed step mode" by setting **HMAX** = **HMIN** = **HO**, but this is not recommended.

3. ORGANIZATION OF ATB INPUT DATA AND CONTROL OF OUTPUT DATA

3.1 Structure of Input File

The input for the ATB program is contained in a single primary input file (FORTRAN unit No. 5). It is a formatted file, structured in a fixed 80 column card format, of alphanumeric data input (see *example.ain*). Each record or line of the file therefore corresponds to the contents of an input card that has a unique identification (e.g., input Card A.1.a). This produces a modular form for the contents of an input file for the ATB program. For example, the A input cards contain the general run parameters, the B input cards contain the inertial and geometric parameters that define the segments and joints of the body, the C input cards contain the parameters that define the prescribed motions, etc.

During the input portion of the ATB program execution, considerable program initialization is performed and a completely annotated listing of the program input is produced on the primary output unit (FORTRAN unit No. 6), as shown at the beginning of *example.aou.*

Following is a summary of all of the input cards. A complete description giving the format for each card, the conditions that specify its necessity, the input parameters to be supplied on each card, and a definition of each of these parameters is provided in the ATB Model Input Manual.

Card A. Run control parameters

A.1.a-c	Date and comment
A.2	Not used
A.3	Dimensional units, components of gravity
A.4	Integrator parameters
A.5	NPRT array for output control

Card B. Physical characteristics of the body

B.1	Body title, number of segments, joints, and of deformable segments
B.1.b-e	Finite element analysis data for deformable segments
B.2.a-b	Physical characteristics of body segments
B.3.a-b	Physical characteristics of joints
B.3.c	Node numbers used to compute rotational deformation for deformable segments
B.4	Joint spring function coefficients, or restoring torque function numbers
B.5	Joint viscous function coefficients
B.6	Integrator convergence tests for body segments
B.7.a-b	Controls for flexible elements

Card C. Prescribed motion

C.1	Vehicle motion title
C.2.a-b	Prescribed motion control parameters
C.3	Unidirectional deceleration tables
C.4	Six degrees-of-freedom deceleration tables
C.5	Spline fit tables

Card D. Contact surface and other environment definitions

D.1.a-b	Number of contact panels, belts, airbags, etc., and water force and joint actuator switches
D.2.a-d	Plane description and input data
D.3.a-c	Simple belt description and input data
D.4.a-h	Airbag description and input data
D.5	Additional contact (hyper)ellipsoid data
D.6	Constraint and tension element input data
D.7	Body segment symmetry options
D.8.a	Spring-damper input data
D.8.b	Spring-damper attachment node for deformable segments
D.9.a	Applied force/torque function input data
D.9.b	Deformable segments' node numbers for applied force/torque

Card E. Function definitions

E.1	Function identification number and title
E.2	Function definition control parameters
E.3	5th degree polynomial coefficients
E.4.a-b	Tabular function definition
E.5	(No longer required by program)
E.6.a-d	Wind force functions input data
E.7.a-d	Joint restoring force functions input data

Card F. Allowed contacts and associated functions

F.1.a-b	Plane/ellipsoid contact definition
F.2.a-b	Belt/segment contact definition
F.3.a-b	Ellipsoid/ellipsoid contact definition
F.4.a-b	Specifications for globalgraphic joint functions
F.5.a	Not used
F.6	Airbag/segment contact definition
F.7.a-b	Wind force function specification
F.8.a-d	Harness/belt system input data

F.9.a-m	Water force simulation data input
F.10	Joint actuator data input

Card G. Initial positioning input

G.1.a	Segment initial velocity data source
G.1.b	Not used
G.2	Initial position and velocity for reference segments
G.3.a-b	Initial segment angular orientation and velocity input data
G.4	Equilibrium control parameters
G.5	Equilibrium control assignments
G.6	Equilibrium constraint assignments

Card H. Tabular time history output control parameters

H.1.a-b	Linear accelerations of selected points on segments
H.2.a-b	Linear velocities of selected points on segments
H.3.a-b	Linear positions of selected points on segments
H.4	Angular accelerations of selected segments
H.5	Angular velocities of selected segments
H.6	Angular orientations of selected segments
H.7	Joint parameters for selected joints
H.8	Wind forces on selected segments
H.9	Joint forces and torques for selected joints
H.10.a-c	Properties of selected groups of segments
H.11	Actuator joint torques
H.12	Parameters for HIC, HSI, and CSI computations

3.2 ATB Output Files

Because of the complexity of the ATB Model and the potential for huge amounts of output from a single simulation, the ATB program was written so that possible output files are controlled for each run. This tailoring of the number of files to be written for each simulation has been somewhat confusing because some aspects of it are explicit (the user sets a flag for the type and frequency of the desired output) and others are implicit (indirectly determined by the type and number of force deflection interactions, etc).

A logical unit is the device or file from which or to which input or output from a FORTRAN program is to be sent. Except for the primary input and output files (FORTRAN unit Nos. 5 and 6), the use of each I/O file is controlled by input parameters contained within the program input file. The ATB model has an open-ended number of required logical units which depends on the amount of output requested by parameters in the input file. Table 2 summarizes major FORTRAN logical units that may be used by the ATB program.

Table 2 Summary of ATB Program I/O Units

Logical Unit	Filename Extension	Type*	Description	Controlling Parameters
1	.SA1, .TP1, .UF1	U or F	Program VIEW input	NPRT (1) & (35) on Card A.5
5	.AIN	F	Primary input	always required
6	.AOU	F	Primary output	always required
21+	.T??	F	Time histories	NPRT (4) on Card A.5 & Cards H.1~ H.12

* Type is F for formatted, U for unformatted file.

3.2.1 View Output (Unit 1)

Logical unit No. 1 is typically an ASCII-formatted output file designed to be used as data input to VIEW, the program that creates the graphics frequently associated with the ATB Model. This output file has an extension name *.sa1*, or *.tp1*. For backward compatibility with an early version of VIEW, an optional unformatted (binary) output file is also included, with an extension name *.uf1*.

The generation of this output file is controlled by the value of **NPRT (1)** that is supplied on input Card A.5. A blank or zero value for **NPRT (1)** will suppress the generation of output file *.sa1* or *.tp1*, whereas a non-zero positive value will produce data records that are equally spaced at every **m*DT** seconds of simulation time starting at 0 time, where **m** is the integer value of **NPRT (1)** and **DT** is defined on input Card A.4.

File *.sa1* and *.tp1* contain fixed initialization data describing the planes, contact ellipsoids, and harness belts. These are followed by records containing the values of time and the corresponding dynamic data, including segment positions in the inertial reference and the direction cosine matrix for each of the body segments. The only difference between the *.sa1* and *.tp1* files is the formatting. The *.sa1* file uses the new structured ASCII graphics output format used by VIEW and is selected by setting **NPRT(35)** to 0. The structured graphics output file is designed for easier troubleshooting and smaller file size. The *.tp1* file uses the old ASCII graphics output format used by older versions of VIEW and is selected by setting **NPRT(35)** to 2.

3.2.2 Primary Output (Unit 6)

The primary output file for the ATB program is logical unit No. 6. It has an extension name *.aou*. Except for injury criteria (HIC, HSI, etc.) results, it is recommended that this file be used mainly for diagnostics and input reference instead of simulation result analysis. Referring to *example.aou* in the Appendix, the primary output file contains the following items:

1. A labeled echo of the ATB program input data.

2. Tables of segment linear and angular position, velocity, and acceleration information, joint forces and torques, the sum of all external forces and torques acting on each segment, and constraint forces data. These data are generated at fixed time intervals of **m*DT** seconds, where **m** is the integer value of **NPRT(3)**. These tables are useful in determining whether the occupant is initially balanced.

3. Tables of the computer elapsed CPU time used by selected subroutines and the number of calls to these subroutines. They are printed at fixed time intervals as specified by **DT** and at a frequency specified by **NPRT (2)**. When **NPRT (2)** is zero, the table is generated only once at the successful completion of an ATB program run.

4. Diagnostic-type output produced at every call to various subroutines, as controlled by the values supplied for **NPRT (8)** to **(28)** on input Card A.5. This output is intended for diagnostic or checkout purposes only, and, if used indiscriminately, can produce voluminous amounts of output.

5. Short descriptions of changes in some of the simulation run conditions are produced as they occur. They include:

    a. Failures of the program integrator convergence tests that cause the integration step to decrease in size. The time, step size, segment and test involved, and the final convergence test parameters are printed. NOTE: These messages are normal and do not indicate an error in the simulation. A stop will occur if the integration step becomes too small.

    b. Changes in the lock conditions of joints as detected by changes in the values of IPIN or IEULER for the various joints. The time, previous and new values of the indicator, and the identification number and nomenclature of the joint involved are printed.

    c. Each time a point is added to or deleted from the set of harness belt reference points, changes are indicated by listing the time, the set of points, and the distance between them.

6. A page containing values of the head injury criterion (HIC), head and chest severity indices (HSI and CSI), and related information.

7. The tabular time histories may be generated on the primary output file as described in the next section.

3.2.3 Tabular Time Histories (Units 21, 22, 23, ...)

The tabular time histories are perhaps the most useful output of the ATB program. Most ATB simulation result analyses are performed with these time history files. These files are designed in such a way as to allow easy data export to spreadsheet software, such as Microsoft Excel and SigmaPlot. Depending on the value of **NPRT(4)**, they may be output at the end of the *.aou* file or to consecutive logical units starting from UNIT21, with one logical unit for each time history. For the latter, each time history file has an extension name *.txx*, where *xx* is the corresponding logical unit number. Their generation, contents, frequency of output, and the manner by which they are generated are completely controlled by program input parameters. The Appendix includes several example time history files.

There are two types of time history files. The first type is controlled by Cards H.1 to H.11. The files in this set primarily contain the body kinematic data and properties. The output of each individual file in this set is optional and is defined by the user's specification in the H cards. If there are any output files of this type, they will be assigned logical unit numbers starting with 21. The second type of output files include contact results, such as deflections, forces, and contact locations, and spring-damper forces. Their output is controlled by the value of **NPRT(18)** on input Card A.5 and an output flag in each contact definition. For plane/ellipsoid and ellipsoid/ellipsoid contacts, the value of **NPRT(18)** determines whether any data will be output. If **NPRT(18)** allows this output, then the user can specify which individual contacts to output on the F.1 and F.3 cards. This gives users the ability to output only those contacts of interest.

Table 3 summarizes the time history files and their control cards. The listing order of the time histories reflects the order in which they are assigned logical unit numbers.

Table 3 Time History Files

Time History	Output Control Cards
Point Linear Accelerations: Components and Resultant	H.1
Point Linear Velocities: Components and Resultant	H.2
Point Linear Positions: Components and Resultant	H.3
Segment Angular Accelerations: Components and Resultant	H.4
Segment Angular Velocities: Components and Resultant	H.5
Segment Angular Positions: Yaw, Pitch, Roll, and Resultant	H.6
Joint Parameters: Lock Condition, Angles, and Resistive Torques	H.7
Segment Wind Forces: Components and Resultant	H.8
Joint Forces and Torques: Components and Resultant	H.9
Total Body Properties: CG Location, Linear and Angular Momentum, Kinetic Energy, Inertial Tensor Matrix, Principal Moments of Inertia and Principal Axes	H.10
Active (Actuator) Joint Torques: Components and Resultant	H.11
Plane/Ellipsoid Contacts: Normal, Friction, and Resultant Contact Forces, Deflection, and Contact Point Coordinates	A.5 and F.1
Simple Belt Contacts: Belt Strain and Anchor Point Forces	A.5
Harness Belt Contacts: Belt Strain and Anchor Point Forces	A.5
Spring Damper Forces: Component and Resultant	A.5
Ellipsoid/Ellipsoid Contacts: Normal, Friction, and Resultant Contact Forces, Deflection, and Contact Point Coordinates	A.5 and F.3
Airbag Contacts: Airbag Parameters and Contact Forces	A.5 and F.6

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APPENDIX A

ATB Simulation Example

A standard sled test simulation is used as the example throughout this User's Guide. In this example, a 167 lb male subject was the occupant restrained using a double shoulder harness and a lap belt with a negative G strap. A generic seat was used with the seat back reclined 13° from vertical and the seat pan inclined 6° from horizontal. The acceleration waveform of the impact sled was an approximate half-sine pulse with a 209 msec impact duration and a 9.47 G amplitude. The ATB simulation time was 300 msec. Figure A-1 shows the simulation graphics generated by the VIEW program. VIEW reads in data from the ATB output file example.sa1 and draws the graphics. Example.sa1 is not included in this appendix since it is merely a data file. Corresponding frames from high speed film are presented to offer a comparison between the ATB simulation results and the actual occupant response. A set of simulation input and output files are included in the following sections. It is recommended that this example be used as a trial run for users learning the ATB program.

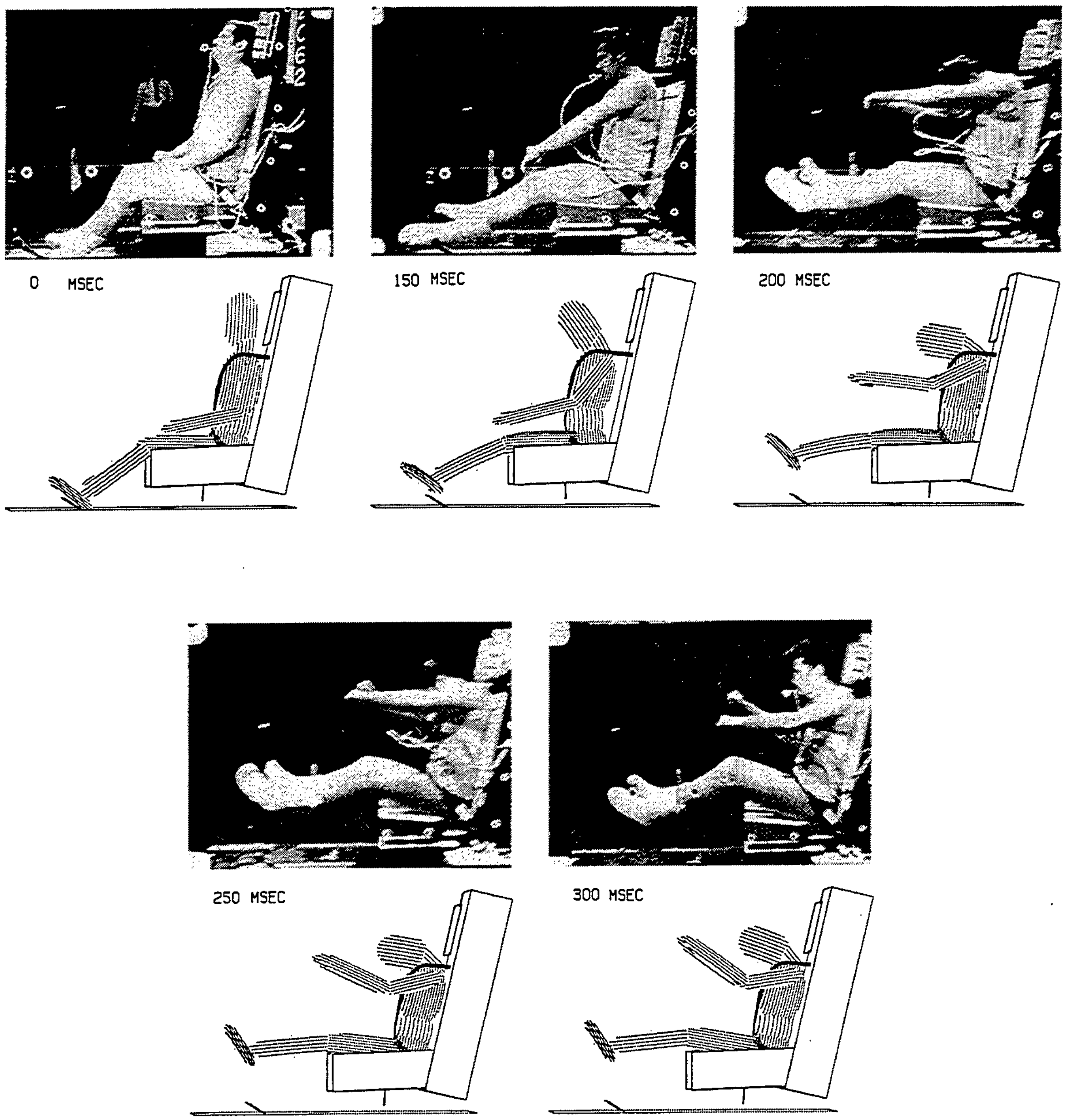

Figure A-1. Sled Test and ATB Simulation

Example.ain File

Example.ain is the ATB Model input file for the sled test simulation. Each line is labeled with a card number at the end of the line. (The term "card" is a carryover from the days of punchcards.) The B Cards are generated using the GEBOD program. The user should refer to the ATB Model Input Manual for detailed variables and input format descriptions.

```
21 FEB 1997    0   00.000000                                                  CARD A1
SIMULATION OF THE HUMAN VOLUNTEER SLED TEST                                   CARD A2
USING NEWLY DEVELOPED HUMAN JOINT CHARACTERISTICS                             CARD A2
 IN. LB.SEC.    0.000000    0.000000    386.0880    0.000000                  CARD A3
  4 150.0020000.0005000.0010000.0000625                                       CARD A4
 5 5 5 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0-1 0 0 0 0 0 0 0 0 0 1CARD A5
 1  5  1 15                                                                   CARD A6
  15    14          MALE HUMAN 167 LB                                         CARD B1
LT  123.597.84590.77400.977304.61706.85004.2530-.4620.00000.83700    1   CARD B2
           .00000.00000.00000
CT  24.8720.13360.07370.200904.29105.97103.3030-1.430.00000.09500    1   CARD B2
           .00000.00000.00000
UT  350.5914.07732.99622.52424.73806.35807.0970.00000.00000-.1080    1   CARD B2
           .0000014.400.00000
N   42.1790.01450.01750.021602.37602.37604.3700-.4750.000001.1710    1   CARD B2
           .00000.00000.00000
H   59.2360.17970.20490.132803.90103.06105.6610-1.115.00000.00000    1   CARD B2
           .0000036.000.00000
RUL 620.313.25680.25550.014403.00103.001011.623.00000-.3210.50900    1   CARD B2
           .00000.00000.00000
RLL 78.0080.49270.50010.056902.29702.297010.188.91900-1.110.87200    1   CARD B2
           .00000.00000.00000
RF  82.0100.03840.03640.006901.38301.90905.2870-.0230-.6270.00000    1   CARD B2
           -4.0008.4000-6.100
LUL 920.313.25680.25550.014403.00103.001011.623.00000.32100.50900    1   CARD B2
           .00000.00000.00000
LLL A8.0080.49270.50010.056902.29702.297010.188.919001.1100.87200    1   CARD B2
           .00000.00000.00000
LF  B2.0100.03840.03640.006901.38301.90905.2870-.0230.62700.00000    1   CARD B2
           4.00008.40006.1000
RUA C4.0180.10680.11310.021601.93901.93906.5350.00000-.2230-.5490    1   CARD B2
           .00000.00000.00000
RLA D3.9140.25680.25550.014401.74201.74209.1950.00000.611001.1510    1   CARD B2
           .00000.00000.00000
LUA E4.0180.10680.11310.021601.93901.93906.5350.00000.22300-.5490    1   CARD B2
           .00000.00000.00000
LLA F3.9140.25680.25550.014401.74201.74209.1950.00000-.61101.1510    1   CARD B2
           .00000.00000.00000
 P       1   0-1.400.00000-2.230-2.340.000002.2100   0.00000.00000      CARD B3
              .00000.00000.00000.000005.0000.00000.00000.00000.00000 3 2 1 3 2 1
 W       2   0-1.680.00000-.8300-.2700.000006.9900   0.00000.00000      CARD B3
              .00000.00000.00000.000005.0000.00000.00000.00000.00000 3 2 1 3 2 1
 NP      3   0-.2200.00000-7.210-.8800.000001.4900   0.00000.00000      CARD B3
              .00000.00000.00000.0000010.000.00000.00000.00000.00000 3 2 1 3 2 1
 HP      4   0.98000.00000-2.500-.8200.000001.9600   0.00000.00000      CARD B3
              .00000.00000.00000.0000010.000.00000.00000.00000.00000 3 2 1 3 2 1
 RH      1   0-.54002.11001.4800-.4100-1.920-7.500   0.00000.00000      CARD B3
             14.00048.000.00000.00000.00000-7.000.00000.00000.00000 3 2 1 3 2 1
 RK      6   1-.2400.360009.7000.63000-.5500-6.890   0.00000.00000      CARD B3
              .00000-66.00.00000.00000.00000.00000.00000.00000.00000 3 2 1 3 2 1
 RA      7   0.39000-.75009.67001.3600-.3100-2.740   0.00000.00000      CARD B3
              .0000065.000.00000.00000.00000.00000.00000.00000.00000 3 2 1 3 2 1
 LH      1   0-.5400-2.1101.4800-.41001.9200-7.500   0.00000.00000      CARD B3
             -14.0048.000.00000.00000.000007.0000.00000.00000.00000 3 2 1 3 2 1
 LK      9   1-.2400-.36009.7000.63000.55000-6.890   0.00000.00000      CARD B3
              .00000-66.00.00000.00000.00000.00000.00000.00000.00000 3 2 1 3 2 1
 LA     10   0.39000.750009.67001.3600.31000-2.740   0.00000.00000      CARD B3
              .0000065.000.00000.00000.00000.00000.00000.00000.00000 3 2 1 3 2 1
 RS      3   0-.93006.5200-4.240.51000-.2200-5.150   0.00000.00000      CARD B3
             59.29079.080.00000.00000.00000.00000.00000.00000.00000 3 2 1 3 2 1
 RE     12   1-.6500-.39005.0200-.5000.31000-7.080   0.00000.00000      CARD B3
             -15.0065.000.00000-15.00.00000.00000.00000.00000.00000 3 2 1 3 2 1
 LS      3   0-.9300-6.520-4.240.51000.22000-5.150   0.00000.00000      CARD B3
             -59.2979.080.00000.00000.00000.00000.00000.00000.00000 3 2 1 3 2 1
```

```
  LE     14    1-.6500.390005.0200-.5000-.3100-7.080   0.00000.00000      CARD B3
                 15.0065.000.00000 15.00.00000.00000.00000.00000.00000 3 2 1 3 2 1
.0000010.000.00000.70000     20.00000.0000010.000.00000.70000     5.000000CARD B4
.0000010.000.00000.70000     20.00000.0000010.000.00000.70000     35.00000CARD B4
.000004.0000.00000.70000     35.00000.0000010.000.00000.70000     35.00000CARD B4
.000004.0000.00000.70000     25.00000.0000010.000.00000.70000     35.00000CARD B4
 -4    .00000.00000.00000    0.000000.00000.20020-8E-04.70000     10.00000CARD B4
 -10  1.8000.00000.70000     60.00000.00000.00000.00000.00000     0.000000CARD B4
 -12  7.0000.00000.70000     35.000005.8378.05646.00000.70000     4.000000CARD B4
 -5    .00000.00000.00000    0.000000.00000.20020-8E-04.70000     10.00000CARD B4
 -11  1.8000.00000.70000     60.00000.00000.00000.00000.00000     0.000000CARD B4
 -15  7.0000.00000.70000     35.000005.8378.05646.00000.70000     4.000000CARD B4
 -1    .00000.00000.00000    0.000000.00000.07450-3E-04.70000     25.00000CARD B4
 -8   1.8000.00000.70000     70.00000.00000.00000.00000.00000     0.000000CARD B4
 -2    .00000.00000.00000    0.000000.00000.07450-3E-04.70000     25.00000CARD B4
 -9   1.8000.00000.70000     70.00000.00000.00000.00000.00000     0.000000CARD B4
.50000.0000030.000.00000.00000                      .00000.00000          CARD B5
.50000.0000030.000.00000.00000                      .00000.00000          CARD B5
.60000.0000030.000.00000.00000                      .00000.00000          CARD B5
.60000.0000030.000.00000.00000                      .00000.00000          CARD B5
.30000.0000030.000.00000.00000                      .00000.00000          CARD B5
.30000.0000030.000.00000.00000                      .00000.00000          CARD B5
.30000.0000030.000.00000.00000                      .00000.00000          CARD B5
.30000.0000030.000.00000.00000                      .00000.00000          CARD B5
.30000.0000030.000.00000.00000                      .00000.00000          CARD B5
.30000.0000030.000.00000.00000                      .00000.00000          CARD B5
.60000.0000030.000.00000.00000                      .00000.00000          CARD B5
.30000.0000030.000.00000.00000                      .00000.00000          CARD B5
.60000.0000030.000.00000.00000                      .00000.00000          CARD B5
.30000.0000030.000.00000.00000                      .00000.00000          CARD B5
.01000.01000.01000.01000.01000.01000.10000.10000.10000.10000.10000.01000CARD B6
.01000.01000.01000.00000.00000.00000.10000.10000.10000.00000.00000.00000CARD B6
.01000.01000.01000.00000.00000.00000.10000.10000.10000.00000.00000.00000CARD B6
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.01000.01000.01000.00000.00000.00000.10000.10000.10000.00000.00000.00000CARD B6
.01000.01000.01000.00000.00000.00000.10000.10000.10000.00000.00000.00000CARD B6
.01000.01000.01000.00000.00000.00000.10000.10000.10000.00000.00000.00000CARD B6
.01000.01000.01000.00000.00000.00000.10000.10000.10000.00000.00000.00000CARD B6
SLED ACCELERATION                                                         CARD C1
.00000.00000.00000.00000.00000.00000.00000     57.00000.00400     0CARD C2
.02560.09520.00140.02560.00140.02560.09520.00140.02560.00140.02560.04690CARD C3A
.02270.11930.21600.554201.76202.22102.75243.67044.61255.65126.59337.4629CARD C3B
8.38098.98489.39559.39559.41969.25059.17819.17818.98488.81578.62258.6225CARD C3C
8.57418.40508.13937.77707.41467.00406.56916.11025.72375.14394.46753.8878CARD C3D
3.25972.55921.8103.98900.26430.55700.50870.24300.00000                 CARD C3E
    12     0     0     0     0     0     1     0     0     0            CARD D1
   1    SEAT CUSHION           0   0                                    CARD D2A
    10.00000     8.000000    -10.00000                                  CARD D2B
    28.01000     8.000000    -11.89000                                  CARD D2C
    10.00000    -8.000000    -10.00000                                  CARD D2D
   2    SEAT BACK              0   0                                    CARD D2A
    1.000000     9.000000    -48.97000                                  CARD D2B
    10.00000     9.000000    -10.00000                                  CARD D2C
    1.000000    -9.000000    -48.97000                                  CARD D2D
   3    FLOOR.                 0   0                                    CARD D2A
    0.000000     12.00000    -1.300000                                  CARD D2B
    60.00000     12.00000    -1.300000                                  CARD D2C
```

```
 0.000000   -12.00000   -1.300000                                            CARD D2D
 4     HEAD PAD                0    0                                        CARD D2A
 2.891687    7.499822   -45.99358                                            CARD D2B
 5.371688    7.499822   -35.28358                                            CARD D2C
 2.891687   -7.500182   -45.99358                                            CARD D2D
 5     SEAT FRONT PANEL.       0    0                                        CARD D2A
 28.01000    8.000000   -11.89000                                            CARD D2B
 26.66000    8.000000   -4.400000                                            CARD D2C
 28.01000   -8.000000   -11.89000                                            CARD D2D
 6     BACK PANEL2. 13 DEGR    0    0                                        CARD D2A
 1.000000    9.000000   -48.97000                                            CARD D2B
 10.00000    9.000000   -10.00000                                            CARD D2C
 1.000000   -9.000000   -48.97000                                            CARD D2D
 7     FIREWALL.               0    0                                        CARD D2A
 60.00000    12.00000   -25.00000                                            CARD D2B
 60.00000   -12.00000   -25.00000                                            CARD D2C
 60.00000    12.00000  -0.7500000                                            CARD D2D
 8     RIGHT SIDE SEAT/IN.     0    0                                        CARD D2A
 8.410000    8.100000   -6.660000                                            CARD D2B
 8.700000    8.100000   -14.73000                                            CARD D2C
 30.58001 .  8.100000   -6.640000                                            CARD D2D
 9     LEFT SIDE SEAT/IN.      0    0                                        CARD D2A
 8.410000   -8.100000   -6.660000                                            CARD D2B
 30.58001   -8.100000   -6.640000                                            CARD D2C
 8.700000   -8.100000   -14.73000                                            CARD D2D
10     RUDDER PEDALS.          0    0                                        CARD D2A
 44.99118    8.999872   -1.423467                                            CARD D2B
 48.27194    8.999872   -3.562127                                            CARD D2C
 44.99118   -9.000128   -1.423467                                            CARD D2D
11     LEFT SIDE PANEL.        0    0                                        CARD D2A
 1.000000   -9.000000   -48.97000                                            CARD D2B
 10.90000   -9.000000   -6.100000                                            CARD D2C
-7.770000   -9.000000   -46.95000                                            CARD D2D
12     RIGHT SIDE PANEL.       0    0                                        CARD D2A
 1.000000    9.000000   -48.97000                                            CARD D2B
-7.770000    9.000000   -46.95000                                            CARD D2C
 10.90000    9.000000   -6.100000                                            CARD D2D
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0                    CARD D7
3     SEGMENT-SEGMENT FCN.     0    0                                        CARD E1
 0.000000   -5.000000    0.000000    0.000000    1.000000                    CARD E2
  6                                                                          CARD E4A
 0.000000    0.000000    1.000000    470.0000    2.000000    889.9999CARD E4B
 3.000000    1220.000    4.000000    1470.000    5.000000    1580.000CARD E4C
 7     R FACTOR.               0    0                                        CARD E1
 0.000000    0.000000   0.7000000    0.000000    0.000000                    CARD E2
13     STIFF SURFACES          0    0                                        CARD E1
 0.000000   -4.000000    0.000000    0.000000    1.000000                    CARD E2
  8                                                                          CARD E4A
 0.000000    0.000000   0.1000000    5.000000   0.2000000    20.00000CARD E4B
0.3000000    40.00000   0.4000000    60.00000    1.000000    560.0001CARD E4C
 2.000000    1200.000    3.000000    4000.000                                CARD E4D
14     FRICTION FUNC.          0    0                                        CARD E1
 0.000000    0.000000   2.0000000    0.000000    2.000000                    CARD E2
19     CF=.25,CREST=.25        0    0                                        CARD E1
 0.000000    0.000000   0.2500000    0.000000    0.000000                    CARD E2
20     DAMPING COEFF. C=100    0    0                                        CARD E1
 0.000000    1.000000    0.000000    0.000000    1.000000                    CARD E2
 0.000000    1000.000    0.000000    0.000000    0.000000    0.000000CARD E3
21     RATE OF DEFLEC.         0    0                                        CARD E1
-40.00000   -150.0000    0.000000    0.000000    1.000000                    CARD E2
 21                                                                          CARD E4A
-40.00000    0.000000   -30.00000    0.000000   -20.00000    0.000000CARD E4B
-10.00000    0.000000    0.000000    0.000000    5.000000    1.000000CARD E4C
 10.00000    1.000000    20.00000   0.9899999    30.00000   0.9650000CARD E4D
```

```
  40.00000   0.9279998   50.00000   0.8600001   60.00000   0.6900000CARD E4E
  70.00000   0.4750000   80.00000   0.3400000   90.00000   0.2600000CARD E4F
  100.0000   0.2000000   110.0000   0.1800000   120.0000  0.09000000CARD E4G
  130.0000  0.06000000   140.0000  0.02500000   150.0000   0.000000CARD E4H
 22   DAMPING COEFF. C=35    0   0                                  CARD E1
  0.000000   1.000000   0.000000    0.000000   1.000000             CARD E2
  0.000000   35.00000   0.000000    0.000000   0.000000    0.000000CARD E3
 29   VERY STIFF BELT.       0   0                                  CARD E1
  0.000000  -4.000000   0.000000    0.000000   1.000000             CARD E2
  12                                                                CARD E4A
  0.000000   0.000000  0.2500000    4000.000  0.3333300    6000.000CARD E4B
 0.4166699   7500.000  0.5000000    11640.00  0.5833300    14700.00CARD E4C
 0.6666998   18210.00  0.7500000    21600.00  0.8333300    25320.00CARD E4D
 0.9166700   30000.00   1.000000    33720.00   4.000000    225000.0CARD E4E
 31   HARNESS  N-G STRAP     0   0                                  CARD E1
  0.000000   10.00000   0.000000    0.000000   0.000000             CARD E2
  0.000000   2500.000   0.000000    0.000000   0.000000    0.000000CARD E3
 33   BELT FRICTION          0   0                                  CARD E1
  0.000000   0.000000  0.9000000    0.000000  0.2000000             CARD E2
 34   HARNESS FRICTION       0   0                                  CARD E1
  0.000000   0.000000  1.9900000    0.000000  1.9900000             CARD E2
999                                                                 CARD E1
  1   RIGHT SHOULDER JOINT                                          CARD E7A
                                                                    CARD E7B
  -4    12                                                          CARD E7C
  60.07121    233.6540   212.3940    12.03720                       CARD E7D
  65.93372    326.3510   258.3800    21.20680                       CARD E7D
  82.40853    356.2500   217.7140    11.67850                       CARD E7D
  91.21090    272.0920   163.5090    5.066480                       CARD E7D
  89.27122    258.4990   176.1420    10.21010                       CARD E7D
  89.62075    288.6960   176.4290    6.454900                       CARD E7D
  84.04031    225.0060   121.3410   -12.06520                       CARD E7D
  80.09302    195.8620   95.93260   -21.24050                       CARD E7D
  77.24643    204.1740   119.9530   -11.66900                       CARD E7D
  80.60311    189.2130   117.3500   -5.125761                       CARD E7D
  99.29332    188.2180   75.28892   -10.24110                       CARD E7D
  84.86960    225.4650   117.3850   -6.466969                       CARD E7D
  2   LEFT SHOULDER JOINT                                           CARD E7A
                                                                    CARD E7B
  -4    12                                                          CARD E7C
  60.07121    233.6540   212.3940    12.03720                       CARD E7D
  84.86960    225.4650   117.3850   -6.466969                       CARD E7D
  99.29332    188.2180   75.28892   -10.24110                       CARD E7D
  80.60311    189.2130   117.3500   -5.125761                       CARD E7D
  77.24643    204.1740   119.9530   -11.66900                       CARD E7D
  80.09302    195.8620   95.93260   -21.24050                       CARD E7D
  84.04031    225.0060   121.3410   -12.06520                       CARD E7D
  89.62075    288.6960   176.4290    6.454900                       CARD E7D
  89.27122    258.4990   176.1420    10.21010                       CARD E7D
  91.21090    272.0920   163.5090    5.066480                       CARD E7D
  82.40853    356.2500   217.7140    11.67850                       CARD E7D
  65.93372    326.3510   258.3800    21.20680                       CARD E7D
  4   RIGHT HIP JOINT                                               CARD E7A
                                                                    CARD E7B
  -4    12                                                          CARD E7C
  63.84941    826.2141   676.1950  -0.2866720                       CARD E7D
  58.28361    826.2141   676.1950  -0.2866720                       CARD E7D
  38.89900    826.2141   676.1950  -0.2866720                       CARD E7D
  36.16820    826.2141   676.1950  -0.2866720                       CARD E7D
  39.74170    826.2141   676.1950  -0.2866720                       CARD E7D
  50.85709    826.2141   676.1950  -0.2866720                       CARD E7D
  63.36500    826.2141   676.1950  -0.2866720                       CARD E7D
  47.66820    826.2141   676.1950  -0.2866720                       CARD E7D
  37.63620    826.2141   676.1950  -0.2866720                       CARD E7D
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    34.85600     826.2141     676.1950   -0.2866720                                      CARD E7D
    38.24630     826.2141     676.1950   -0.2866720                                      CARD E7D
    54.14160     826.2141     676.1950   -0.2866720                                      CARD E7D
   5     LEFT HIP JOINT                                                                  CARD E7A
                                                                                         CARD E7B
    -4     12                                                                            CARD E7C
    63.84941     826.2141     676.1950   -0.2866720                                      CARD E7D
    54.14160     826.2141     676.1950   -0.2866720                                      CARD E7D
    38.24630     826.2141     676.1950   -0.2866720                                      CARD E7D
    34.85600     826.2141     676.1950   -0.2866720                                      CARD E7D
    37.63620     826.2141     676.1950   -0.2866720                                      CARD E7D
    47.66820     826.2141     676.1950   -0.2866720                                      CARD E7D
    63.36500     826.2141     676.1950   -0.2866720                                      CARD E7D
    50.85709     826.2141     676.1950   -0.2866720                                      CARD E7D
    39.74170     826.2141     676.1950   -0.2866720                                      CARD E7D
    36.16820     826.2141     676.1950   -0.2866720                                      CARD E7D
    38.89900     826.2141     676.1950   -0.2866720                                      CARD E7D
    58.28361     826.2141     676.1950   -0.2866720                                      CARD E7D
   8     RIGHT ELBOW JOINT                                                               CARD E7A
                                                                                         CARD E7B
    -5      2                                                                            CARD E7C
    30.00000     90.30700     271.4830     218.8050     45.72250                         CARD E7D
    34.00000     60.39060     131.6870     19.23500    -44.79070                         CARD E7D
   9     LEFT ELBOW JOINT                                                                CARD E7A
                                                                                         CARD E7B
    -5      2                                                                            CARD E7C
    30.00000     90.30700     271.4830     218.8050     45.72250                         CARD E7D
    34.00000     60.39060     131.6870     19.23500    -44.79070                         CARD E7D
  10     RIGHT KNEE JOINT                                                                CARD E7A
                                                                                         CARD E7B
    -4      2                                                                            CARD E7C
    23.00000     52.19941     441.0020     176.3340                                      CARD E7D
    34.00000     153.8690     408.4461     250.5860                                      CARD E7D
  11     LEFT KNEE JOINT                                                                 CARD E7A
                                                                                         CARD E7B
    -4      2                                                                            CARD E7C
    23.00000     52.19941     441.0020     176.3340                                      CARD E7D
    34.00000     153.8690     408.4461     250.5860                                      CARD E7D
  12     RIGHT ANKLE JOINT                                                               CARD E7A
                                                                                         CARD E7B
    -4      2                                                                            CARD E7C
    4.000000     179.0880     67.88540     133.8270                                      CARD E7D
    4.000000     167.7160    -12.13370     132.9940                                      CARD E7D
  15     LEFT ANKLE JOINT                                                                CARD E7A
                                                                                         CARD E7B
    -4      2                                                                            CARD E7C
    4.000000     179.0880     67.88540     133.8270                                      CARD E7D
    4.000000     167.7160    -12.13370     132.9940                                      CARD E7D
999                                                                                      CARD E7A
   3    5    2    1    0    0    0    0    0    2    0    0                             CARD F1A
   1   16    1    1   13  -20  -21    0   14    1                                       CARD F1B
   1   16    6    6   13  -20  -21    0   14    1                                       CARD F1B
   1   16    9    9   13  -20  -21    0   14    1                                       CARD F1B
   2   16    1    1   13  -20  -21    0   14    1                                       CARD F1B
   2   16    2    2   13  -20  -21    0   14    1                                       CARD F1B
   2   16    3    3   13  -20  -21    0   14    1                                       CARD F1B
   2   16   13   13   13  -22  -21    0   14    1                                       CARD F1B
   2   16   15   15   13  -22  -21    0   14    1                                       CARD F1B
   3   16    8    8   13  -22  -21    0   14   -1                                       CARD F1B
   3   16   11   11   13  -22  -21    0   14   -1                                       CARD F1B
   4   16    5    5   13  -22  -21    0   14    1                                       CARD F1B
  10   16    8    8   13  -22  -21    0   14    1                                       CARD F1B
  10   16   11   11   13  -22  -21    0   14    1                                       CARD F1B
   0    0    0    0    0    2    2    0    1    1    1    0    1    0    0                CARD F3A
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 6   6  13  13   3   0   7   0  19                                                      CARD F3B
 6   6   9   9   3   0   7   0  19                                                      CARD F3B
 7   7  10  10   3   0   7   0  19                                                      CARD F3B
 7   7  11  11   3   0   7   0  19                                                      CARD F3B
 9   9  15  15   3   0   7   0  19                                                      CARD F3B
10  10   8   8   3   0   7   0  19                                                      CARD F3B
11  11   8   8   3   0   7   0  19                                                      CARD F3B
13  13  15  15   3   0   7   0  19                                                      CARD F3B
 0   0   0   0   0   0   0   0   0   0   0   0   0   0                                  CARD F4A
 4                                                                                      CARD F8A
 9  18  18   4                                                                          CARD F8B
29   0   0   0   0   -0.200000   0   0   0                                              CARD F8C
16   0   1   1   0   0   0   0   0   7.000000   -8.000000   -8.500000   F8D1
  0.000000    0.000000    0.000000   2.400000   22.000000   -0.300000   F8D2
 1   1   0   0   0   0   0   0  33   2.570000   -5.650000   -0.381000   F8D1
  0.000000    0.000000    0.000000   0.000000    0.000000    0.000000   F8D2
 1   1   0   0   0   0   0   0  33   3.689000   -3.594000   -1.249000   F8D1
  0.000000    0.000000    0.000000   0.000000    0.000000    0.000000   F8D2
 1   1   0   0   0   0   0   0  33   3.812415   -2.658020   -1.588378   F8D1
  0.000000    0.000000    0.000000   0.000000    0.000000    0.000000   F8D2
 1   1   0   0   0   0   0   0   0   3.900000    0.000000   -2.335000   F8D1
  0.000000    0.000000    0.000000   0.000000    1.000000    0.000000   F8D2
 1   1   0   0   0   0   0   0  33   3.812415    2.658020   -1.588378   F8D1
  0.000000    0.000000    0.000000   0.000000    0.000000    0.000000   F8D2
 1   1   0   0   0   0   0   0  33   3.698000    3.594000   -1.249000   F8D1
  0.000000    0.000000    0.000000   0.000000    0.000000    0.000000   F8D2
 1   1   0   0   0   0   0   0  33   2.570000    5.650000   -0.381000   F8D1
  0.000000    0.000000    0.000000   0.000000    0.000000    0.000000   F8D2
16   0   1   1   0   0   0   0   0   7.000000    8.000000   -8.500000   F8D1
  0.000000    0.000000    0.000000   2.400000   22.000000   -0.300000   F8D2
31   0   0   0   0   -0.100000   0   0   0                                              CARD F8C
16   0   1   1   0   0   0   0   0  -1.500000    0.000140  -32.000000   F8D1
  0.000000    0.000000    0.000000   0.500000    0.000000    0.500000   F8D2
 3   3   0   0   0   0   0   0  34  -0.592107   -3.229789   -6.406097   F8D1
  0.000000    0.000000    0.000000   0.000000    0.000000    0.000000   F8D2
 3   3   0   0   0   0   0   0  34   0.197222   -3.220030   -6.313524   F8D1
  0.000000    0.000000    0.000000   0.000000    0.000000    0.000000   F8D2
 3   3   0   0   0   0   0   0  34   1.000000   -3.210000   -6.200000   F8D1
  0.000000    0.000000    0.000000   0.000000    0.000000    0.000000   F8D2
 3   3   0   0   0   0   0   0  34   1.729085   -3.200000   -5.903608   F8D1
  0.000000    0.000000    0.000000   0.000000    0.000000    0.000000   F8D2
 3   3   0   0   0   0   0   0  34   2.829251   -3.125510   -5.483449   F8D1
  0.000000    0.000000    0.000000   0.000000    0.000000    0.000000   F8D2
 3   3   0   0   0   0   0   0  34   3.455790   -3.042912   -4.528134   F8D1
  0.000000    0.000000    0.000000   0.000000    0.000000    0.000000   F8D2
 3   3   0   0   0   0   0   0  34   3.947432   -2.836730   -3.472554   F8D1
  0.000000    0.000000    0.000000   0.000000    0.000000    0.000000   F8D2
 3   3   0   0   0   0   0   0  34   4.343934   -2.664911   -2.675975   F8D1
  0.000000    0.000000    0.000000   0.000000    0.000000    0.000000   F8D2
 3   3   0   0   0   0   0   0  34   4.623846   -2.493092   -1.803066   F8D1
  0.000000    0.000000    0.000000   0.000000    0.000000    0.000000   F8D2
 3   3   0   0   0   0   0   0  34   4.721993   -2.286909   -0.962208   F8D1
  0.000000    0.000000    0.000000   0.000000    0.000000    0.000000   F8D2
 3   3   0   0   0   0   0   0  34   4.705504   -2.149454   -0.480676   F8D1
  0.000000    0.000000    0.000000   0.000000    0.000000    0.000000   F8D2
 3   3   0   0   0   0   0   0  34   4.706552   -1.875891    0.730580   F8D1
  0.000000    0.000000    0.000000   0.000000    0.000000    0.000000   F8D2
 3   3   0   0   0   0   0   0  34   4.597802   -1.756925    1.387208   F8D1
  0.000000    0.000000    0.000000   0.000000    0.000000    0.000000   F8D2
 2   2   0   0   0   0   0   0  34   4.127623   -0.451147   -0.532688   F8D1
  0.000000    0.000000    0.000000   0.000000    0.000000    0.000000   F8D2
 2   2   0   0   0   0   0   0  34   4.297456   -0.332015    0.203587   F8D1
  0.000000    0.000000    0.000000   0.000000    0.000000    0.000000   F8D2
 2   2   0   0   0   0   0   0  34   4.098295   -0.213856    0.861432   F8D1
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  0.000000    0.000000    0.000000    0.000000    0.000000    0.000000     F8D2
 1   1   1   1   0   0   0   0   0    3.900000    0.000000   -2.335000     F8D1
  0.000000    0.000000    0.000000    0.000000    1.000000   -2.000000     F8D2
31   0   0   0   0  -0.100000   0   0   0                               CARD F8C
16   0   1   1   0   0   0   0   0   -1.500000    0.000140  -32.000000     F8D1
  0.000000    0.000000    0.000000    0.500000    0.000000    0.500000     F8D2
 3   3   0   0   0   0   0   0  34   -0.592107    3.229789   -6.406097     F8D1
  0.000000    0.000000    0.000000    0.000000    0.000000    0.000000     F8D2
 3   3   0   0   0   0   0   0  34    0.197222    3.220030   -6.313524     F8D1
  0.000000    0.000000    0.000000    0.000000    0.000000    0.000000     F8D2
 3   3   0   0   0   0   0   0  34    1.000000    3.210000   -6.200000     F8D1
  0.000000    0.000000    0.000000    0.000000    0.000000    0.000000     F8D2
 3   3   0   0   0   0   0   0  34    1.729085    3.200000   -5.903608     F8D1
  0.000000    0.000000    0.000000    0.000000    0.000000    0.000000     F8D2
 3   3   0   0   0   0   0   0  34    2.829251    3.125510   -5.483449     F8D1
  0.000000    0.000000    0.000000    0.000000    0.000000    0.000000     F8D2
 3   3   0   0   0   0   0   0  34    3.455790    3.042912   -4.528134     F8D1
  0.000000    0.000000    0.000000    0.000000    0.000000    0.000000     F8D2
 3   3   0   0   0   0   0   0  34    3.947432    2.836730   -3.472554     F8D1
  0.000000    0.000000    0.000000    0.000000    0.000000    0.000000     F8D2
 3   3   0   0   0   0   0   0  34    4.343934    2.664911   -2.675975     F8D1
  0.000000    0.000000    0.000000    0.000000    0.000000    0.000000     F8D
 3   3   0   0   0   0   0   0  34    4.623846    2.493092   -1.803066     F8D1
  0.000000    0.000000    0.000000    0.000000    0.000000    0.000000     F8D2
 3   3   0   0   0   0   0   0  34    4.721993    2.286909   -0.962208     F8D1
  0.000000    0.000000    0.000000    0.000000    0.000000    0.000000     F8D2
 3   3   0   0   0   0   0   0  34    4.705504    2.149454   -0.480676     F8D1
  0.000000    0.000000    0.000000    0.000000    0.000000    0.000000     F8D2
 3   3   0   0   0   0   0   0  34    4.706552    1.875891    0.730580     F8D1
  0.000000    0.000000    0.000000    0.000000    0.000000    0.000000     F8D2
 3   3   0   0   0   0   0   0  34    4.597802    1.756925    1.387208     F8D1
  0.000000    0.000000    0.000000    0.000000    0.000000    0.000000     F8D2
 2   2   0   0   0   0   0   0  34    4.127623    0.451147   -0.532688     F8D1
  0.000000    0.000000    0.000000    0.000000    0.000000    0.000000     F8D2
 2   2   0   0   0   0   0   0  34    4.297456    0.332015    0.203587     F8D1
  0.000000    0.000000    0.000000    0.000000    0.000000    0.000000     F8D2
 2   2   0   0   0   0   0   0  34    4.098295    0.213856    0.861432     F8D1
  0.000000    0.000000    0.000000    0.000000    0.000000    0.000000     F8D2
 1   1   1   1   0   0   0   0   0    3.900000    0.000000   -2.335000     F8D1
  0.000000    0.000000    0.000000    0.000000    1.000000   -2.000000     F8D2
31   0   0   0   0  -0.100000   0   0   0                               CARD F8C
16   0   1   1   0   0   0   0   0   18.966637   -0.000137   -2.716074     F8D1
  0.000000    0.000000    0.000000   -1.000000    0.000000    1.000000     F8D2
 1   1   0   0   0   0   0   0  33    4.478610    0.000000    0.868376     F8D1
  0.000000    0.000000    0.000000    0.000000    0.000000    0.000000     F8D2
 1   1   0   0   0   0   0   0  33    4.497387   -0.000026   -0.831519     F8D1
  0.000000    0.000000    0.000000    0.000000    0.000000    0.000000     F8D2
 1   1   1   1   0   0   0   0   0    3.900000    0.000000   -2.335000     F8D1
  0.000000    0.000000    0.000000    0.000000    0.000000    1.000000     F8D2
     0.0         0.0         0.0   0   0   0   0   0                    CARD G1A
13.88821.000010414 -15.12504  0.000000  0.000000  0.000000              CARD G2
0.000000  13.00000  0.000000  0.000000  0.000000  0.000000  3  2  1  0CARD G3A
0.000000  12.00000  0.000000  0.000000  0.000000  0.000000  3  2  1  0CARD G3A
0.000000  10.00000  0.000000  0.000000  0.000000  0.000000  3  2  1  0CARD G3A
0.000000  5.000000  0.000000  0.000000  0.000000  0.000000  3  2  1  0CARD G3A
0.000000  3.000000  0.000000  0.000000  0.000000  0.000000  3  2  1  0CARD G3A
4.000000  91.24997  0.000000  0.000000  0.000000  0.000000  3  2  1  0CARD G3A
0.000000  53.40000  0.000000  0.000000  0.000000  0.000000  3  2  1  0CARD G3A
0.000000  128.8000  0.000000  0.000000  0.000000  0.000000  3  2  1  0CARD G3A
356.0000  91.25000  0.000000  0.000000  0.000000  0.000000  3  2  1  0CARD G3A
0.000000  53.40000  0.000000  0.000000  0.000000  0.000000  3  2  1  0CARD G3A
0.000000  128.8000  0.000000  0.000000  0.000000  0.000000  3  2  1  0CARD G3A
0.000000  12.00000  0.000000  0.000000  0.000000  0.000000  3  2  1  0CARD G3A
0.000000  70.00000  0.000000  0.000000  0.000000  0.000000  3  2  1 12CARD G3A
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0.000000   12.00000   0.000000   0.000000   0.000000   0.000000   3   2   1   0CARD G3A
0.000000   70.00000   0.000000   0.000000   0.000000   0.000000   3   2   1  14CARD G3A
   2   0  -5     6.200000     0.000000     3.218000  0                        CARD H1A
       0  -3     4.738000     0.000000     0.000000                           CARD H1B
   2   0   5     6.200000     0.000000     3.218000  0                        CARD H2A
       0   3     4.738000     0.000000     0.000000                           CARD H2B
   2   0   5     6.200000     0.000000     3.218000  0                        CARD H3A
       0   3     4.738000     0.000000     0.000000                           CARD H3B
   2   3  12  12  13   0                                                      CARD H4
   2   3  12  12  13   0                                                      CARD H5
   2   3  12  12  13   0                                                      CARD H6
  14   0   5   0   8   0   6   0   9   0   7   0  10   0  11   0  13   0  12   0  14   0  1CARD H7
       0   2   0   3   0   4   0                                              CARD H7
   0                                                                          CARD H8
   4   1   6   6   7   3  12  12  13   0                                      CARD H9
   0                                                                          CARD H10
 0    0                                                                       CARD H12
```

Portion of Example.aou File

Example.aou is the primary output file (Unit 6) of the sled test simulation. Because of its large size, only a portion of the file (results up to 10 msec) is presented here. The first part of the file contains the input data with all the variables clearly labeled. The second part of the file contains the simulation results at predetermined time intervals.

```
DEVELOPED BY CALSPAN CORP., P.O. BOX 400, BUFFALO NY 14225
AND BY J&J TECHNOLOGIES INC., ORCHARD PARK, NY 14127

FOR THE ARMSTRONG AEROSPACE MEDICAL RESEARCH LABORATORY
WRIGHT PATTERSON AIR FORCE BASE
UNDER CONTRACTS F33615-75C-5002,-78C-0516 AND -80C-05117

AND FOR THE NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION,
U.S. DEPARTMENT OF TRANSPORTATION, UNDER CONTRACTS
FH-11-7592, HS-053-2-485, HS-6-01300 AND HS-6-01410,

MODIFIED BY GESAC, INC. TO INCORPORATE WATER FORCES,

AND BY ARMSTRONG LAB. FOR ROBOTIC MOTION SIMULATION
AND FINITE ELEMENT MODEL OF DEFORMABLE SEGMENT


PROGRAM DOCUMENTATION: NHTSA REPORT NOS. DOT-HS-801-507
THROUGH 510 (FORMERLY CALSPAN REPORT NO. ZQ-5180-L-1),
AVAILABLE FROM NTIS (ACCESSION NOS. PB-241692,3,4 AND 5),
APPENDIXES A-J TO THE ABOVE (AVAILABLE FROM CALSPAN),
AND REPORT NOS. AMRL-TR-75-14 (NTIS NO. AD-A014 816),
AFAMRL-TR-80-14 (NTIS NO. AD-A088 029), AND
AFAMRL-TR-83-073 (NTIS NO. AD-B079 184).

THE MOST RECENT DOCUMENTATION IS IN REPORT NOS.
AAMRL-TR-88-007 (NTIS NO. AD-A197 940),
AAMRL-TR-88-009 (NTIS NO. AD-A198 726),
AAMRL-TR-88-043 (NTIS NO. AD-A203 566).


PROGRAM ATBV.1, (LATEST REVISION 08/01/97)


EXECUTED ON THE DEC 5000/200PXG WORKSTATION
AT AL/CFBV, WRIGHT-PATTERSON AFB, OHIO.

  21 FEB 1997   IRSIN=   0  IRSOUT=   0  RSTIME =  0.0000                          CARDS A

SIMULATION OF THE HUMAN VOLUNTEER SLED TEST                     CARD A2
USING NEWLY DEVELOPED HUMAN JOINT CHARACTERISTICS               CARD A2
```

UNITL = IN.   UNITM = LB.   UNITT = SEC.   GRAVITY VECTOR = (0.0000,   0.0000, 386.0880)   G = 386.0880

NDINT =   4   NSTEPS = 150   DT =0.002000   H0 =0.000500   HMAX =0.001000   HMIN =0.000063

0 NPRT ARRAY

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
5	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	1

1 CRASH VICTIM   MALE HUMAN 167 LB   15 SEGMENTS   14 JOINTS

PAGE 2
CARD B.1
CARDS B.2

SEGMENT			WEIGHT	PRINCIPAL MOMENTS OF INERTIA (LB.-SEC.**2- IN.)			SEGMENT CONTACT ELLIPSOID SEMIAXES (IN.)			CENTER (IN.)			PRINCIPAL AXES (DEG)		
I	SYM	PLOT	(LB.)	X	Y	Z	X	Y	Z	X	Y	Z	YAW	PITCH	ROLL
1	LT	1	23.597	0.8459	0.7740	0.9773	4.617	6.850	4.253	-0.462	0.000	0.837	0.00	0.00	0.00
2	CT	2	4.872	0.1336	0.0737	0.2009	4.291	5.971	3.303	-1.430	0.000	0.095	0.00	0.00	0.00
3	UT	3	50.591	4.0773	2.9962	2.5242	4.738	6.358	7.097	0.000	0.000	-0.108	0.00	14.40	0.00
4	N	4	2.179	0.0145	0.0175	0.0216	2.376	2.376	4.370	-0.475	0.000	1.171	0.00	0.00	0.00
5	H	5	9.236	0.1797	0.2049	0.1328	3.901	3.061	5.661	-1.115	0.000	0.000	0.00	36.00	0.00
6	RUL	6	20.313	0.2568	0.2555	0.0144	3.001	3.001	11.623	0.000	-0.321	0.509	0.00	0.00	0.00
7	RLL	7	8.008	0.4927	0.5001	0.0569	2.297	2.297	10.188	0.919	-1.110	0.872	0.00	0.00	0.00
8	RF	8	2.010	0.0384	0.0364	0.0069	1.383	1.909	5.287	-0.023	-0.627	0.000	-4.00	8.40	-6.10
9	LUL	9	20.313	0.2568	0.2555	0.0144	3.001	3.001	11.623	0.000	0.321	0.509	0.00	0.00	0.00
10	LLL	A	8.008	0.4927	0.5001	0.0569	2.297	2.297	10.188	0.919	1.110	0.872	0.00	0.00	0.00
11	LF	B	2.010	0.0384	0.0364	0.0069	1.383	1.909	5.287	-0.023	0.627	0.000	4.00	8.40	6.10
12	RUA	C	4.018	0.1068	0.1131	0.0216	1.939	1.939	6.535	0.000	-0.223	-0.549	0.00	0.00	0.00
13	RLA	D	3.914	0.2568	0.2555	0.0144	1.742	1.742	9.195	0.000	0.611	1.151	0.00	0.00	0.00
14	LUA	E	4.018	0.1068	0.1131	0.0216	1.939	1.939	6.535	0.000	0.223	-0.549	0.00	0.00	0.00
15	LLA	F	3.914	0.2568	0.2555	0.0144	1.742	1.742	9.195	0.000	-0.611	1.151	0.00	0.00	0.00

CARDS B.3

JOINT					LOCATION(IN.) - SEG(JNT)			LOCATION(IN.) - SEG(J+1)			JOINT AXIS(DEG) - SEG(JNT)						JOINT AXIS(DEG) - SEG(J+1)					
J	SYM	PLOT	JNT	PIN	X	Y	Z	X	Y	Z	ID1	YAW	ID2	PITCH	ID3	ROLL	ID4	YAW	ID5	PITCH	ID6	ROLL
1	P		1	0	-1.400	0.000	-2.230	-2.340	0.000	2.210	3	0.00	2	0.00	1	0.00	3	0.00	2	5.00	1	0.00
2	W		2	0	-1.680	0.000	-0.830	-0.270	0.000	6.990	3	0.00	2	0.00	1	0.00	3	0.00	2	5.00	1	0.00
3	NP		3	0	-0.220	0.000	-7.210	-0.880	0.000	1.490	3	0.00	2	0.00	1	0.00	3	0.00	2	10.00	1	0.00
4	HP		4	0	0.980	0.000	-2.500	-0.820	0.000	1.960	3	0.00	2	0.00	1	0.00	3	0.00	2	10.00	1	0.00
5	RH		1	0	-0.540	2.110	1.480	-0.410	-1.920	-7.500	3	14.00	2	48.00	1	0.00	3	0.00	2	0.00	1	-7.00
6	RK		6	1	-0.240	0.360	9.700	0.630	-0.550	-6.890	3	0.00	2	-66.00	1	0.00	3	0.00	2	0.00	1	0.00
7	RA		7	0	0.390	-0.750	9.670	1.360	-0.310	-2.740	3	0.00	2	65.00	1	0.00	3	0.00	2	0.00	1	0.00
8	LH		1	0	-0.540	-2.110	1.480	-0.410	1.920	-7.500	3	-14.00	2	48.00	1	0.00	3	0.00	2	0.00	1	7.00
9	LK		9	1	-0.240	-0.360	9.700	0.630	0.550	-6.890	3	0.00	2	-66.00	1	0.00	3	0.00	2	0.00	1	0.00
10	LA		10	0	0.390	0.750	9.670	1.360	0.310	-2.740	3	0.00	2	65.00	1	0.00	3	0.00	2	0.00	1	0.00
11	RS		3	0	-0.930	6.520	-4.240	0.510	-0.220	-5.150	3	59.29	2	79.08	1	0.00	3	0.00	2	0.00	1	0.00
12	RE		12	1	-0.650	-0.390	5.020	-0.500	0.310	-7.080	3	-15.00	2	65.00	1	0.00	3	-15.00	2	0.00	1	0.00
13	LS		3	0	-0.930	-6.520	-4.240	0.510	0.220	-5.150	3	-59.29	2	79.08	1	0.00	3	0.00	2	0.00	1	0.00
14	LE		14	1	-0.650	0.390	5.020	-0.500	-0.310	-7.080	3	15.00	2	65.00	1	0.00	3	15.00	2	0.00	1	0.00

1 JOINT TORQUE CHARACTERISTICS

PAGE 3
CARDS B.4

FLEXURAL SPRING CHARACTERISTICS   TORSIONAL SPRING CHARACTERISTICS

	JOINT	SPRING COEF. (IN. LB./DEG**J) LINEAR (J=1)	QUADRATIC (J=2)	CUBIC (J=3)	ENERGY DISSIPATION COEF.	JOINT STOP (DEG)	SPRING COEF. (IN. LB./DEG**J) LINEAR (J=1)	QUADRATIC (J=2)	CUBIC (J=3)	ENERGY DISSIPATION COEF.	JOINT STOP (DEG)
1	P	0.000	10.000	0.000	0.700	20.000	0.000	10.000	0.000	0.700	5.000
2	W	0.000	10.000	0.000	0.700	20.000	0.000	10.000	0.000	0.700	35.000
3	NP	0.000	4.000	0.000	0.700	35.000	0.000	10.000	0.000	0.700	35.000
4	HP	0.000	4.000	0.000	0.700	25.000	0.000	10.000	0.000	0.700	35.000
5	RH	-4.000	0.000	0.000	0.000	0.000	0.000	0.200	-0.001	0.700	10.000
6	RK	-10.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	RA	-12.000	0.000	0.000	0.000	0.000	5.838	0.056	0.000	0.700	4.000
8	LH	-5.000	0.000	0.000	0.000	0.000	0.000	0.200	-0.001	0.700	10.000
9	LK	-11.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	LA	-15.000	0.000	0.000	0.000	0.000	5.838	0.056	0.000	0.700	4.000
11	RS	-1.000	0.000	0.000	0.000	0.000	0.000	0.075	0.000	0.700	25.000
12	RE	-8.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13	LS	-2.000	0.000	0.000	0.000	0.000	0.000	0.075	0.000	0.700	25.000
14	LE	-9.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

CARDS B.5

JOINT VISCOUS CHARACTERISTICS AND LOCK-UNLOCK CONDITIONS

	JOINT	VISCOUS COEFFICIENT (IN. LB.SEC./DEG)	COULOMB FRICTION COEF. (IN. LB.)	FULL FRICTION ANGULAR VELOCITY (DEG/SEC.)	MAX TORQUE FOR A LOCKED JOINT (IN. LB.)	MIN TORQUE FOR UNLOCKED JOINT (IN. LB.)	MIN. ANG. VELOCITY FOR UNLOCKED JOINT (RAD/SEC.)	IMPULSE RESTITUTION COEFFICIENT
1	P	0.500	0.00	30.00	0.00	0.00	0.00	0.000
2	W	0.500	0.00	30.00	0.00	0.00	0.00	0.000
3	NP	0.600	0.00	30.00	0.00	0.00	0.00	0.000
4	HP	0.600	0.00	30.00	0.00	0.00	0.00	0.000
5	RH	0.300	0.00	30.00	0.00	0.00	0.00	0.000
6	RK	0.300	0.00	30.00	0.00	0.00	0.00	0.000
7	RA	0.300	0.00	30.00	0.00	0.00	0.00	0.000
8	LH	0.300	0.00	30.00	0.00	0.00	0.00	0.000
9	LK	0.300	0.00	30.00	0.00	0.00	0.00	0.000
10	LA	0.300	0.00	30.00	0.00	0.00	0.00	0.000
11	RS	0.600	0.00	30.00	0.00	0.00	0.00	0.000
12	RE	0.300	0.00	30.00	0.00	0.00	0.00	0.000
13	LS	0.600	0.00	30.00	0.00	0.00	0.00	0.000
14	LE	0.300	0.00	30.00	0.00	0.00	0.00	0.000

SEGMENT INTEGRATION CONVERGENCE TEST INPUT

CARDS B.6

SEGMENT NO.	SYM	ANGULAR VELOCITIES (RAD/SEC.) MAG. TEST	ABS. ERROR	REL. ERROR	LINEAR VELOCITIES (IN./SEC.) MAG. TEST	ABS. ERROR	REL. ERROR	ANGULAR ACCELERATIONS (RAD/SEC.**2) MAG. TEST	ABS. ERROR	REL. ERROR	LINEAR ACCELERATIONS (IN./SEC.**2) MAG. TEST	ABS. ERROR	REL. ERROR
1	LT	0.010	0.010	0.0100	0.010	0.010	0.0100	0.100	0.100	0.1000	0.100	0.100	0.0100

2	CT	0.010	0.010	0.0100	0.000	0.000	0.0000	0.100	0.100	0.1000	0.000	0.000	0.0000
3	UT	0.010	0.010	0.0100	0.000	0.000	0.0000	0.100	0.100	0.1000	0.000	0.000	0.0000
4	N	0.010	0.010	0.0100	0.000	0.000	0.0000	0.100	0.100	0.1000	0.000	0.000	0.0000
5	H	0.010	0.010	0.0100	0.000	0.000	0.0000	0.100	0.100	0.1000	0.000	0.000	0.0000
6	RUL	0.010	0.010	0.0100	0.000	0.000	0.0000	0.100	0.100	0.1000	0.000	0.000	0.0000
7	RLL	0.010	0.010	0.0100	0.000	0.000	0.0000	0.100	0.100	0.1000	0.000	0.000	0.0000
8	RF	0.010	0.010	0.0100	0.000	0.000	0.0000	0.100	0.100	0.1000	0.000	0.000	0.0000
9	LUL	0.010	0.010	0.0100	0.000	0.000	0.0000	0.100	0.100	0.1000	0.000	0.000	0.0000
10	LLL	0.010	0.010	0.0100	0.000	0.000	0.0000	0.100	0.100	0.1000	0.000	0.000	0.0000
11	LF	0.010	0.010	0.0100	0.000	0.000	0.0000	0.100	0.100	0.1000	0.000	0.000	0.0000
12	RUA	0.010	0.010	0.0100	0.000	0.000	0.0000	0.100	0.100	0.1000	0.000	0.000	0.0000
13	RLA	0.010	0.010	0.0100	0.000	0.000	0.0000	0.100	0.100	0.1000	0.000	0.000	0.0000
14	LUA	0.010	0.010	0.0100	0.000	0.000	0.0000	0.100	0.100	0.1000	0.000	0.000	0.0000
15	LLA	0.010	0.010	0.0100	0.000	0.000	0.0000	0.100	0.100	0.1000	0.000	0.000	0.0000

1 VEHICLE DECELERATION INPUTS

SLED ACCELERATION

CARD C1

YAW	PITCH	ROLL	VIPS	VTIME	X0(X)	X0(Y)	X0(Z)	NATAB	AT0	ADT	I1	I3	MSEG
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	57	0.00000	0.00400	0	0	0

0 UNIDIRECTIONAL VEHICLE POSITION TABLES

TIME (MSEC)	ACC (G)	VELOCITY (IN./SEC.)	POSITION (IN.)	TIME (MSEC)	ACC (G)	VELOCITY (IN./SEC.)	POSITION (IN.)
0.00000	0.03	0.0000	0.00000	200.00000	1.81	-355.3802	-24.92547
4.00000	0.10	-0.1143	-0.00023	204.00000	0.99	-357.5293	-26.35169
8.00000	0.00	-0.2099	-0.00089	208.00000	0.26	-358.4846	-27.78412
12.00000	0.03	-0.2370	-0.00178	212.00000	0.56	-359.1627	-29.21935
16.00000	0.00	-0.2641	-0.00279	216.00000	0.51	-360.0295	-30.65767
20.00000	0.03	-0.2791	-0.00385	220.00000	0.24	-360.6070	-32.09907
24.00000	0.10	-0.3665	-0.00511	224.00000	0.00	-360.7917	-33.54200
28.00000	0.00	-0.4259	-0.00672				
32.00000	0.03	-0.4316	-0.00845				
36.00000	0.00	-0.4462	-0.01021				
40.00000	0.03	-0.4608	-0.01202				
44.00000	0.05	-0.5227	-0.01399				
48.00000	0.02	-0.5823	-0.01620				
52.00000	0.12	-0.6919	-0.01870				
56.00000	0.22	-0.9508	-0.02193				
60.00000	0.55	-1.4336	-0.02630				
64.00000	1.76	-3.1102	-0.03499				
68.00000	2.22	-6.1765	-0.05331				
72.00000	2.75	-10.0075	-0.08543				
76.00000	3.67	-14.9639	-0.13489				
80.00000	4.61	-21.3567	-0.20705				
84.00000	5.65	-29.2945	-0.30784				
88.00000	6.59	-38.7618	-0.44345				
92.00000	7.46	-49.6095	-0.61973				
96.00000	8.38	-61.8374	-0.84216				
100.00000	8.98	-75.2717	-1.11612				

```
   104.00000       9.40      -89.4894      -1.44538
   108.00000       9.40     -103.9962      -1.83235
   112.00000       9.42     -118.5217      -2.27738
   116.00000       9.25     -132.9259      -2.78033
   120.00000       9.18     -147.1435      -3.34053
   124.00000       9.18     -161.3426      -3.95756
   128.00000       8.98     -175.3925      -4.63108
   132.00000       8.82     -189.1407      -5.36024
   136.00000       8.62     -202.6092      -6.14383
   140.00000       8.62     -215.9316      -6.98092
   144.00000       8.57     -229.2166      -7.87123
   148.00000       8.40     -242.3399      -8.81446
   152.00000       8.14     -255.1274      -9.80950
   156.00000       7.78     -267.4176     -10.85478
   160.00000       7.41     -279.1482     -11.94810
   164.00000       7.00     -290.2850     -13.08718
   168.00000       6.57     -300.7690     -14.26951
   172.00000       6.11     -310.5503     -15.49236
   176.00000       5.72     -319.6789     -16.75304
   180.00000       5.14     -328.0830     -18.04889
   184.00000       4.47     -335.5171     -19.37641
   188.00000       3.89     -341.9751     -20.73171
   192.00000       3.26     -347.5005     -22.11097
   196.00000       2.56     -351.9999     -23.51034
1  VEHICLE PATHS TO GROUND                                                                                     PAGE    6

 THE GROUND (INERTIAL) SEGMENT IS REPRESENTED HERE BY A 0.
 THE COORD CATEGORY REFERS TO THE COORDINATE SYSTEM IN WHICH THE VEHICLE DATA ARE SPECIFIED.
 A NEGATIVE VALUE FOR COORD INDICATES THAT THE DATA REPRESENT ACCELEROMETER DATA.

    VEH  COORD    VEHICLE PATH TO GROUND
    VEH   GRND    GRND
     16     0       0

1    NPL     NBLT     NBAG     NELP      NQ      NSD   NHRNSS  NWINDF  NJNTFOLD  NFORCE   NWATER   NEXTCD          PAGE    7
      12       0        0        0        0        0        1        0        0        0        0        0       CARD D.1a
0 PLANE INPUTS                                                                                               CARDS D.2
0 PLANE NO.   1     SEAT CUSHION

                  X            Y            Z
  POINT 1      10.0000       8.0000     -10.0000
  POINT 2      28.0100       8.0000     -11.8900
  POINT 3      10.0000      -8.0000     -10.0000
0 PLANE NO.   2     SEAT BACK

                  X            Y            Z
  POINT 1       1.0000       9.0000     -48.9700
  POINT 2      10.0000       9.0000     -10.0000
  POINT 3       1.0000      -9.0000     -48.9700
0 PLANE NO.   3     FLOOR.
```

```
                 X          Y          Z
  POINT 1      0.0000    12.0000    -1.3000
  POINT 2     60.0000    12.0000    -1.3000
  POINT 3      0.0000   -12.0000    -1.3000
0 PLANE NO.   4    HEAD PAD

                 X          Y          Z
  POINT 1      2.8917     7.4998   -45.9936
  POINT 2      5.3717     7.4998   -35.2836
  POINT 3      2.8917    -7.5002   -45.9936
0 PLANE NO.   5    SEAT FRONT PANEL.

                 X          Y          Z
  POINT 1     28.0100     8.0000   -11.8900
  POINT 2     26.6600     8.0000    -4.4000
  POINT 3     28.0100    -8.0000   -11.8900
0 PLANE NO.   6    BACK PANEL2. 13 DEGR

                 X          Y          Z
  POINT 1      1.0000     9.0000   -48.9700
  POINT 2     10.0000     9.0000   -10.0000
  POINT 3      1.0000    -9.0000   -48.9700
0 PLANE NO.   7    FIREWALL.

                 X          Y          Z
  POINT 1     60.0000    12.0000   -25.0000
  POINT 2     60.0000   -12.0000   -25.0000
  POINT 3     60.0000    12.0000    -0.7500
1 PLANE INPUTS

0 PLANE NO.   8    RIGHT SIDE SEAT/IN.

                 X          Y          Z
  POINT 1      8.4100     8.1000    -6.6600
  POINT 2      8.7000     8.1000   -14.7300
  POINT 3     30.5800     8.1000    -6.6400
0 PLANE NO.   9    LEFT SIDE SEAT/IN.

                 X          Y          Z
  POINT 1      8.4100    -8.1000    -6.6600
  POINT 2     30.5800    -8.1000    -6.6400
  POINT 3      8.7000    -8.1000   -14.7300
0 PLANE NO.  10    RUDDER PEDALS.

                 X          Y          Z
  POINT 1     44.9912     8.9999    -1.4235
  POINT 2     48.2719     8.9999    -3.5621
  POINT 3     44.9912    -9.0001    -1.4235
0 PLANE NO.  11    LEFT SIDE PANEL.

                 X          Y          Z
```

```
  POINT 1        1.0000      -9.0000     -48.9700
  POINT 2       10.9000      -9.0000      -6.1000
  POINT 3       -7.7700      -9.0000     -46.9500
0 PLANE NO.  12     RIGHT SIDE PANEL.

                   X            Y            Z
  POINT 1        1.0000       9.0000     -48.9700
  POINT 2       -7.7700       9.0000     -46.9500
  POINT 3       10.9000       9.0000      -6.1000
0 BODY SEGMENT SYMMETRY INPUT                                                                       CARD D.7

  SEG NO.   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15
0 NSYM(J)   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
1                                                                                                    PAGE    9
 FUNCTION NO.   3    SEGMENT-SEGMENT FCN.                    NTI( 3) =    1                          CARDS E

          D0             D1             D2             D3             D4
        0.0000        -5.0000         0.0000         0.0000         1.0000


      FIRST PART OF FUNCTION -    6 TABULAR POINTS

      D                  F(D)
      0.000000           0.0000
      1.000000         470.0000
      2.000000         889.9999
      3.000000        1220.0000
      4.000000        1470.0000
      5.000000        1580.0000



 FUNCTION NO.   7    R FACTOR.                               NTI( 7) =   19                          CARDS E

          D0             D1             D2             D3             D4
        0.0000         0.0000         0.7000         0.0000         0.0000

      FUNCTION IS CONSTANT     0.700000
1                                                                                                    PAGE   10
 FUNCTION NO.  13    STIFF SURFACES                          NTI(13) =   24                          CARDS E

          D0             D1             D2             D3             D4
        0.0000        -4.0000         0.0000         0.0000         1.0000


      FIRST PART OF FUNCTION -    8 TABULAR POINTS
```

D	F(D)
0.000000	0.0000
0.100000	5.0000
0.200000	20.0000
0.300000	40.0000
0.400000	60.0000
1.000000	560.0001
2.000000	1200.0000
3.000000	4000.0000

FUNCTION NO. 14 FRICTION FUNC. NTI(14) = 46 CARDS E

D0	D1	D2	D3	D4
0.0000	0.0000	2.0000	0.0000	2.0000

FUNCTION IS CONSTANT 2.000000

FUNCTION NO. 19 CF=.25,CREST=.25 NTI(19) = 51 CARDS E

D0	D1	D2	D3	D4
0.0000	0.0000	0.2500	0.0000	0.0000

FUNCTION IS CONSTANT 0.250000

FUNCTION NO. 20 DAMPING COEFF. C=100 NTI(20) = 56 CARDS E

D0	D1	D2	D3	D4
0.0000	1.0000	0.0000	0.0000	1.0000

FIRST PART OF FUNCTION - 5TH DEGREE POLYNOMIAL

A0	A1	A2	A3	A4	A5
0.000000	1000.000000	0.000000	0.000000	0.000000	0.000000

FUNCTION NO. 21 RATE OF DEFLEC. NTI(21) = 67 CARDS E

D0	D1	D2	D3	D4
-40.0000	-150.0000	0.0000	0.0000	1.0000

FIRST PART OF FUNCTION - 21 TABULAR POINTS

D	F(D)
-40.000000	0.0000
-30.000000	0.0000
-20.000000	0.0000
-10.000000	0.0000
0.000000	0.0000
5.000000	1.0000
10.000000	1.0000
20.000000	0.9900
30.000000	0.9650
40.000000	0.9280
50.000000	0.8600
60.000000	0.6900
70.000000	0.4750
80.000000	0.3400
90.000000	0.2600
100.000000	0.2000
110.000000	0.1800
120.000000	0.0900
130.000000	0.0600
140.000000	0.0250
150.000000	0.0000

FUNCTION NO. 22 DAMPING COEFF. C=35 NTI(22) = 115 CARDS E

D0	D1	D2	D3	D4
0.0000	1.0000	0.0000	0.0000	1.0000

FIRST PART OF FUNCTION - 5TH DEGREE POLYNOMIAL

A0	A1	A2	A3	A4	A5
0.000000	35.000000	0.000000	0.000000	0.000000	0.000000

FUNCTION NO. 29 VERY STIFF BELT. NTI(29) = 126

D0	D1	D2	D3	D4
0.0000	-4.0000	0.0000	0.0000	1.0000

FIRST PART OF FUNCTION - 12 TABULAR POINTS

D	F(D)
0.000000	0.0000
0.250000	4000.0000
0.333330	6000.0000
0.416670	7500.0000
0.500000	11640.0000
0.583330	14700.0000
0.666700	18210.0000
0.750000	21600.0000
0.833330	25320.0000
0.916670	30000.0000
1.000000	33720.0000
4.000000	225000.0000

FUNCTION NO. 31 HARNESS N-G STRAP NTI(31) = 156 CARDS E

D0	D1	D2	D3	D4
0.0000	10.0000	0.0000	0.0000	0.0000

FIRST PART OF FUNCTION - 5TH DEGREE POLYNOMIAL

A0	A1	A2	A3	A4	A5
0.000000	2500.000000	0.000000	0.000000	0.000000	0.000000

FUNCTION NO. 33 BELT FRICTION NTI(33) = 167 CARDS E

D0	D1	D2	D3	D4
0.0000	0.0000	0.9000	0.0000	0.2000

FUNCTION IS CONSTANT 0.900000

FUNCTION NO. 34 HARNESS FRICTION NTI(34) = 172 CARDS E

D0	D1	D2	D3	D4

0.0000	0.0000	1.9900	0.0000	1.9900

FUNCTION IS CONSTANT 1.990000

1 JOINT FORCE FUNCTION NO. 1 RIGHT SHOULDER JOINT NTI(1) = 177

D0	D1	D2	D3	REF. SEGMENT
0.0000	0.0000	0.0000	0.0000	0.0000

0 FUNCTION IS COEFFICIENTS OF 3 ORDER POLYNOMIALS IN (THETA-THETA0) FOR 12 VALUES OF PHI.

		COEFFICIENTS OF (THETA-THETA0)**N		
PHI	THETA0	N = 1	N = 2	N = 3
-180.00	60.071	233.6540	212.3940	12.03720
-150.00	65.934	326.3510	258.3800	21.20680
-120.00	82.409	356.2500	217.7140	11.67850
-90.00	91.211	272.0920	163.5090	5.066480
-60.00	89.271	258.4990	176.1420	10.21010
-30.00	89.621	288.6960	176.4290	6.454900
0.00	84.040	225.0060	121.3410	-12.06520
30.00	80.093	195.8620	95.93260	-21.24050
60.00	77.246	204.1740	119.9530	-11.66900
90.00	80.603	189.2130	117.3500	-5.125761
120.00	99.293	188.2180	75.28892	-10.24110
150.00	84.870	225.4650	117.3850	-6.466969

1 JOINT FORCE FUNCTION NO. 2 LEFT SHOULDER JOINT NTI(2) = 232

D0	D1	D2	D3	REF. SEGMENT
0.0000	0.0000	0.0000	0.0000	0.0000

0 FUNCTION IS COEFFICIENTS OF 3 ORDER POLYNOMIALS IN (THETA-THETA0) FOR 12 VALUES OF PHI.

		COEFFICIENTS OF (THETA-THETA0)**N		
PHI	THETA0	N = 1	N = 2	N = 3
-180.00	60.071	233.6540	212.3940	12.03720
-150.00	84.870	225.4650	117.3850	-6.466969
-120.00	99.293	188.2180	75.28892	-10.24110
-90.00	80.603	189.2130	117.3500	-5.125761
-60.00	77.246	204.1740	119.9530	-11.66900
-30.00	80.093	195.8620	95.93260	-21.24050
0.00	84.040	225.0060	121.3410	-12.06520
30.00	89.621	288.6960	176.4290	6.454900
60.00	89.271	258.4990	176.1420	10.21010
90.00	91.211	272.0920	163.5090	5.066480
120.00	82.409	356.2500	217.7140	11.67850

150.00	65.934	326.3510	258.3800	21.20680

1 JOINT FORCE FUNCTION NO. 4 RIGHT HIP JOINT NTI(4) = 287

D0	D1	D2	D3	REF. SEGMENT
0.0000	0.0000	0.0000	0.0000	0.0000

0 FUNCTION IS COEFFICIENTS OF 3 ORDER POLYNOMIALS IN (THETA-THETA0) FOR 12 VALUES OF PHI.

		COEFFICIENTS OF (THETA-THETA0)**N		
PHI	THETA0	N = 1	N = 2	N = 3
-180.00	63.849	826.2141	676.1950	-0.2866720
-150.00	58.284	826.2141	676.1950	-0.2866720
-120.00	38.899	826.2141	676.1950	-0.2866720
-90.00	36.168	826.2141	676.1950	-0.2866720
-60.00	39.742	826.2141	676.1950	-0.2866720
-30.00	50.857	826.2141	676.1950	-0.2866720
0.00	63.365	826.2141	676.1950	-0.2866720
30.00	47.668	826.2141	676.1950	-0.2866720
60.00	37.636	826.2141	676.1950	-0.2866720
90.00	34.856	826.2141	676.1950	-0.2866720
120.00	38.246	826.2141	676.1950	-0.2866720
150.00	54.142	826.2141	676.1950	-0.2866720

1 JOINT FORCE FUNCTION NO. 5 LEFT HIP JOINT NTI(5) = 342

D0	D1	D2	D3	REF. SEGMENT
0.0000	0.0000	0.0000	0.0000	0.0000

0 FUNCTION IS COEFFICIENTS OF 3 ORDER POLYNOMIALS IN (THETA-THETA0) FOR 12 VALUES OF PHI.

		COEFFICIENTS OF (THETA-THETA0)**N		
PHI	THETA0	N = 1	N = 2	N = 3
-180.00	63.849	826.2141	676.1950	-0.2866720
-150.00	54.142	826.2141	676.1950	-0.2866720
-120.00	38.246	826.2141	676.1950	-0.2866720
-90.00	34.856	826.2141	676.1950	-0.2866720
-60.00	37.636	826.2141	676.1950	-0.2866720
-30.00	47.668	826.2141	676.1950	-0.2866720
0.00	63.365	826.2141	676.1950	-0.2866720
30.00	50.857	826.2141	676.1950	-0.2866720
60.00	39.742	826.2141	676.1950	-0.2866720
90.00	36.168	826.2141	676.1950	-0.2866720
120.00	38.899	826.2141	676.1950	-0.2866720
150.00	58.284	826.2141	676.1950	-0.2866720

1 JOINT FORCE FUNCTION NO. 8 RIGHT ELBOW JOINT NTI(8) = 397

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         D0             D1             D2             D3        REF. SEGMENT
       0.0000         0.0000         0.0000         0.0000        0.0000


0 FUNCTION IS COEFFICIENTS OF  4 ORDER POLYNOMIALS IN (THETA-THETA0) FOR  2 VALUES OF PHI.

                           COEFFICIENTS OF (THETA-THETA0)**N
    PHI     THETA0            N = 1               N = 2               N = 3               N = 4

  -180.00   30.000         90.30700            271.4830            218.8050            45.72250
     0.00   34.000         60.39060            131.6870             19.23500          -44.79070
1 JOINT FORCE FUNCTION NO.   9    LEFT ELBOW JOINT              NTI( 9) =  414                                      PAGE   20
                                                                                                                 CARDS E.7

         D0             D1             D2             D3        REF. SEGMENT
       0.0000         0.0000         0.0000         0.0000        0.0000


0 FUNCTION IS COEFFICIENTS OF  4 ORDER POLYNOMIALS IN (THETA-THETA0) FOR  2 VALUES OF PHI.

                           COEFFICIENTS OF (THETA-THETA0)**N
    PHI     THETA0            N = 1               N = 2               N = 3               N = 4

  -180.00   30.000         90.30700            271.4830            218.8050            45.72250
     0.00   34.000         60.39060            131.6870             19.23500          -44.79070
1 JOINT FORCE FUNCTION NO.  10    RIGHT KNEE JOINT              NTI(10) =  431                                      PAGE   21
                                                                                                                 CARDS E.7

         D0             D1             D2             D3        REF. SEGMENT
       0.0000         0.0000         0.0000         0.0000        0.0000


0 FUNCTION IS COEFFICIENTS OF  3 ORDER POLYNOMIALS IN (THETA-THETA0) FOR  2 VALUES OF PHI.

                           COEFFICIENTS OF (THETA-THETA0)**N
    PHI     THETA0            N = 1               N = 2               N = 3

  -180.00   23.000         52.19941            441.0020            176.3340
     0.00   34.000         153.8690            408.4461            250.5860
1 JOINT FORCE FUNCTION NO.  11    LEFT KNEE JOINT               NTI(11) =  446                                      PAGE   22
                                                                                                                 CARDS E.7

         D0             D1             D2             D3        REF. SEGMENT
       0.0000         0.0000         0.0000         0.0000        0.0000


0 FUNCTION IS COEFFICIENTS OF  3 ORDER POLYNOMIALS IN (THETA-THETA0) FOR  2 VALUES OF PHI.

                           COEFFICIENTS OF (THETA-THETA0)**N
    PHI     THETA0            N = 1               N = 2               N = 3
```

```
 -180.00    23.000        52.19941          441.0020          176.3340
    0.00    34.000       153.8690           408.4461          250.5860
1 JOINT FORCE FUNCTION NO.  12    RIGHT ANKLE JOINT           NTI(12) =  461                                PAGE   23
                                                                                                           CARDS E.7

          D0             D1             D2             D3         REF. SEGMENT
        0.0000         0.0000         0.0000         0.0000         0.0000


0 FUNCTION IS COEFFICIENTS OF  3 ORDER POLYNOMIALS IN (THETA-THETA0) FOR  2 VALUES OF PHI.

                                COEFFICIENTS OF (THETA-THETA0)**N
     PHI      THETA0              N = 1               N = 2               N = 3

  -180.00     4.000          179.0880            67.88540            133.8270
     0.00     4.000          167.7160           -12.13370            132.9940
1 JOINT FORCE FUNCTION NO.  15    LEFT ANKLE JOINT            NTI(15) =  476                                PAGE   24
                                                                                                           CARDS E.7

          D0             D1             D2             D3         REF. SEGMENT
        0.0000         0.0000         0.0000         0.0000         0.0000


0 FUNCTION IS COEFFICIENTS OF  3 ORDER POLYNOMIALS IN (THETA-THETA0) FOR  2 VALUES OF PHI.

                                COEFFICIENTS OF (THETA-THETA0)**N
     PHI      THETA0              N = 1               N = 2               N = 3

  -180.00     4.000          179.0880            67.88540            133.8270
     0.00     4.000          167.7160           -12.13370            132.9940
1 ALLOWED CONTACTS AND ASSOCIATED FUNCTIONS                                                                 PAGE   25
0                                                                                                          CARDS F.1
0      PLANE          SEGMENT  FORCE DEFLECTION      INERTIAL SPIKE          R FACTOR             G FACTOR         FRICTION COEF. OPT
0       1- 16          1-  1      13                    -20                  -21                   0                  14          1
 SEAT CUSHION           LT  STIFF SURFACES       DAMPING COEFF. C=100 RATE OF DEFLEC.                          FRICTION FUNC.
0       1- 16          6-  6      13                    -20                  -21                   0                  14          1
 SEAT CUSHION           RUL STIFF SURFACES       DAMPING COEFF. C=100 RATE OF DEFLEC.                          FRICTION FUNC.
0       1- 16          9-  9      13                    -20                  -21                   0                  14          1
 SEAT CUSHION           LUL STIFF SURFACES       DAMPING COEFF. C=100 RATE OF DEFLEC.                          FRICTION FUNC.
0       2- 16          1-  1      13                    -20                  -21                   0                  14          1
 SEAT BACK              LT  STIFF SURFACES       DAMPING COEFF. C=100 RATE OF DEFLEC.                          FRICTION FUNC.
0       2- 16          2-  2      13                    -20                  -21                   0                  14          1
 SEAT BACK              CT  STIFF SURFACES       DAMPING COEFF. C=100 RATE OF DEFLEC.                          FRICTION FUNC.
0       2- 16          3-  3      13                    -20                  -21                   0                  14          1
 SEAT BACK              UT  STIFF SURFACES       DAMPING COEFF. C=100 RATE OF DEFLEC.                          FRICTION FUNC.
0       2- 16         13- 13      13                    -22                  -21                   0                  14          1
 SEAT BACK              RLA STIFF SURFACES       DAMPING COEFF. C=35  RATE OF DEFLEC.                          FRICTION FUNC.
0       2- 16         15- 15      13                    -22                  -21                   0                  14          1
 SEAT BACK              LLA STIFF SURFACES       DAMPING COEFF. C=35  RATE OF DEFLEC.                          FRICTION FUNC.
0       3- 16          8-  8      13                    -22                  -21                   0                  14         -1
 FLOOR.                 RF  STIFF SURFACES       DAMPING COEFF. C=35  RATE OF DEFLEC.                          FRICTION FUNC.
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0      3- 16          11- 11      13               -22              -21                  0            14          -1
 FLOOR.                  LF  STIFF SURFACES      DAMPING COEFF. C=35  RATE OF DEFLEC.                 FRICTION FUNC.
0       4- 16          5-  5      13               -22              -21                  0            14           1
 HEAD PAD                H   STIFF SURFACES      DAMPING COEFF. C=35  RATE OF DEFLEC.                 FRICTION FUNC.
0      10- 16          8-  8      13               -22              -21                  0            14           1
 RUDDER PEDALS.          RF  STIFF SURFACES      DAMPING COEFF. C=35  RATE OF DEFLEC.                 FRICTION FUNC.
0      10- 16         11- 11      13               -22              -21                  0            14           1
 RUDDER PEDALS.          LF  STIFF SURFACES      DAMPING COEFF. C=35  RATE OF DEFLEC.                 FRICTION FUNC.
0                                                                                                           CARDS F.3
0     SEGMENT          SEGMENT  FORCE DEFLECTION    INERTIAL SPIKE        R FACTOR          G FACTOR      FRICTION COEF. OPT
0       6-  6         13- 13       3                  0                   7                  0            19           0
          RUL            RLA SEGMENT-SEGMENT FCN.                     R FACTOR.                        CF=.25,CREST=.25
0       6-  6          9-  9       3                  0                   7                  0            19           0
          RUL            LUL SEGMENT-SEGMENT FCN.                     R FACTOR.                        CF=.25,CREST=.25
0       7-  7         10- 10       3                  0                   7                  0            19           0
          RLL            LLL SEGMENT-SEGMENT FCN.                     R FACTOR.                        CF=.25,CREST=.25
0       7-  7         11- 11       3                  0                   7                  0            19           0
          RLL            LF  SEGMENT-SEGMENT FCN.                     R FACTOR.                        CF=.25,CREST=.25
0       9-  9         15- 15       3                  0                   7                  0            19           0
          LUL            LLA SEGMENT-SEGMENT FCN.                     R FACTOR.                        CF=.25,CREST=.25
0      10- 10          8-  8       3                  0                   7                  0            19           0
          LLL            RF  SEGMENT-SEGMENT FCN.                     R FACTOR.                        CF=.25,CREST=.25
0      11- 11          8-  8       3                  0                   7                  0            19           0
          LF             RF  SEGMENT-SEGMENT FCN.                     R FACTOR.                        CF=.25,CREST=.25
0      13- 13         15- 15       3                  0                   7                  0            19           0
          RLA            LLA SEGMENT-SEGMENT FCN.                     R FACTOR.                        CF=.25,CREST=.25
1 HARNESS-BELT SYSTEM INPUT                                                                                    PAGE   26
                                                                                                            CARDS F.8
  NO. OF HARNESSES =    1

  NO. OF BELTS PER HARNESS =      4
0 FOR HARNESS NO.  1 NO. OF POINTS PER BELT =    9  18  18   4
0 HARNESS NO.  1 BELT NO.  1 FUNCTION NOS.    29     0     0     0     0  REFERENCE SLACK =    -0.200  IN.

0     K     KS     KE     NT    NPD    NDR    FUNCTION NOS.                                                 CARDS F.8.D

      1     16      0    133     1      1     0     0     0     0     0
      2      1      1    139     0      0     0     0     0     0    33
      3      1      1    145     0      0     0     0     0     0    33
      4      1      1    151     0      0     0     0     0     0    33
      5      1      1    157     0      0     0     0     0     0     0
      6      1      1    163     0      0     0     0     0     0    33
      7      1      1    169     0      0     0     0     0     0    33
      8      1      1    175     0      0     0     0     0     0    33
      9     16      0    181     1      1     0     0     0     0     0
0              BASE REFERENCE ( IN.)        ADJUSTED REFERENCE ( IN.)          OFFSET ( IN.)           PREFERRED DIRECTION ( IN.)
      K        X        Y        Z          X        Y        Z           X        Y        Z          X        Y        Z

      1      7.000   -8.000   -8.500      7.000   -8.000   -8.500       0.000    0.000    0.000      2.400   22.000   -0.300
      2      2.570   -5.650   -0.381      2.572   -5.655   -0.381      -0.462    0.000    0.837      0.000    0.000    0.000
      3      3.689   -3.594   -1.249      3.689   -3.594   -1.249      -0.462    0.000    0.837      0.000    0.000    0.000
```

4	3.812	-2.658	-1.588	3.867	-2.696	-1.611	-0.462	0.000	0.837	0.000	0.000	0.000
5	3.900	0.000	-2.335	3.871	0.000	-2.318	-0.462	0.000	0.837	0.000	1.000	0.000
6	3.812	2.658	-1.588	3.867	2.696	-1.611	-0.462	0.000	0.837	0.000	0.000	0.000
7	3.698	3.594	-1.249	3.692	3.589	-1.247	-0.462	0.000	0.837	0.000	0.000	0.000
8	2.570	5.650	-0.381	2.572	5.655	-0.381	-0.462	0.000	0.837	0.000	0.000	0.000
9	7.000	8.000	-8.500	7.000	8.000	-8.500	0.000	0.000	0.000	2.400	22.000	-0.300

0 HARNESS NO. 1 BELT NO. 2 FUNCTION NOS. 31 0 0 0 0 REFERENCE SLACK = -0.100 IN.

CARDS F.8.D

0 K	KS	KE	NT	NPD	NDR	FUNCTION NOS.				
10	16	0	193	1	1	0	0	0	0	0
11	3	3	199	0	0	0	0	0	0	34
12	3	3	205	0	0	0	0	0	0	34
13	3	3	211	0	0	0	0	0	0	34
14	3	3	217	0	0	0	0	0	0	34
15	3	3	223	0	0	0	0	0	0	34
16	3	3	229	0	0	0	0	0	0	34
17	3	3	235	0	0	0	0	0	0	34
18	3	3	241	0	0	0	0	0	0	34
19	3	3	247	0	0	0	0	0	0	34
20	3	3	253	0	0	0	0	0	0	34
21	3	3	259	0	0	0	0	0	0	34
22	3	3	265	0	0	0	0	0	0	34
23	3	3	271	0	0	0	0	0	0	34
24	2	2	277	0	0	0	0	0	0	34
25	2	2	283	0	0	0	0	0	0	34
26	2	2	289	0	0	0	0	0	0	34
27	1	1	295	1	1	0	0	0	0	0

0	BASE REFERENCE (IN.)			ADJUSTED REFERENCE (IN.)			OFFSET (IN.)			PREFERRED DIRECTION (IN.)		
K	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z
10	-1.500	0.000	-32.000	-1.500	0.000	-32.000	0.000	0.000	0.000	0.500	0.000	0.500
11	-0.592	-3.230	-6.406	-0.568	-3.096	-6.140	0.000	0.000	-0.108	0.000	0.000	0.000
12	0.197	-3.220	-6.314	0.193	-3.143	-6.162	0.000	0.000	-0.108	0.000	0.000	0.000
13	1.000	-3.210	-6.200	0.970	-3.114	-6.014	0.000	0.000	-0.108	0.000	0.000	0.000
14	1.729	-3.200	-5.904	1.665	-3.081	-5.685	0.000	0.000	-0.108	0.000	0.000	0.000
15	2.829	-3.126	-5.483	2.588	-2.859	-5.016	0.000	0.000	-0.108	0.000	0.000	0.000
16	3.456	-3.043	-4.528	3.197	-2.815	-4.190	0.000	0.000	-0.108	0.000	0.000	0.000
17	3.947	-2.837	-3.473	3.709	-2.665	-3.263	0.000	0.000	-0.108	0.000	0.000	0.000
18	4.344	-2.665	-2.676	4.036	-2.476	-2.486	0.000	0.000	-0.108	0.000	0.000	0.000
19	4.624	-2.493	-1.803	4.273	-2.304	-1.666	0.000	0.000	-0.108	0.000	0.000	0.000
20	4.722	-2.287	-0.962	4.421	-2.141	-0.901	0.000	0.000	-0.108	0.000	0.000	0.000
21	4.706	-2.149	-0.481	4.476	-2.045	-0.457	0.000	0.000	-0.108	0.000	0.000	0.000
22	4.707	-1.876	0.731	4.520	-1.801	0.702	0.000	0.000	-0.108	0.000	0.000	0.000
23	4.598	-1.757	1.387	4.474	-1.709	1.350	0.000	0.000	-0.108	0.000	0.000	0.000
24	4.128	-0.451	-0.533	4.219	-0.461	-0.545	-1.430	0.000	0.095	0.000	0.000	0.000
25	4.297	-0.332	0.204	4.276	-0.330	0.203	-1.430	0.000	0.095	0.000	0.000	0.000
26	4.098	-0.214	0.861	4.137	-0.216	0.870	-1.430	0.000	0.095	0.000	0.000	0.000
27	3.900	0.000	-2.335	3.871	0.000	-2.318	-0.462	0.000	0.837	0.000	1.000	-2.000

0 HARNESS NO. 1 BELT NO. 3 FUNCTION NOS. 31 0 0 0 0 REFERENCE SLACK = -0.100 IN.

0 CARDS F.8.D

K	KS	KE	NT	NPD	NDR	FUNCTION NOS.				
28	16	0	307	1	1	0	0	0	0	0
29	3	3	313	0	0	0	0	0	0	34
30	3	3	319	0	0	0	0	0	0	34
31	3	3	325	0	0	0	0	0	0	34
32	3	3	331	0	0	0	0	0	0	34
33	3	3	337	0	0	0	0	0	0	34
34	3	3	343	0	0	0	0	0	0	34
35	3	3	349	0	0	0	0	0	0	34
36	3	3	355	0	0	0	0	0	0	34
37	3	3	361	0	0	0	0	0	0	34
38	3	3	367	0	0	0	0	0	0	34
39	3	3	373	0	0	0	0	0	0	34
40	3	3	379	0	0	0	0	0	0	34
41	3	3	385	0	0	0	0	0	0	34
42	2	2	391	0	0	0	0	0	0	34
43	2	2	397	0	0	0	0	0	0	34
44	2	2	403	0	0	0	0	0	0	34
45	1	1	409	1	1	0	0	0	0	0

0

K	BASE REFERENCE (IN.) X	Y	Z	ADJUSTED REFERENCE (IN.) X	Y	Z	OFFSET (IN.) X	Y	Z	PREFERRED DIRECTION (IN.) X	Y	Z
28	-1.500	0.000	-32.000	-1.500	0.000	-32.000	0.000	0.000	0.000	0.500	0.000	0.500
29	-0.592	3.230	-6.406	-0.568	3.096	-6.140	0.000	0.000	-0.108	0.000	0.000	0.000
30	0.197	3.220	-6.314	0.193	3.143	-6.162	0.000	0.000	-0.108	0.000	0.000	0.000
31	1.000	3.210	-6.200	0.970	3.114	-6.014	0.000	0.000	-0.108	0.000	0.000	0.000
32	1.729	3.200	-5.904	1.665	3.081	-5.685	0.000	0.000	-0.108	0.000	0.000	0.000
33	2.829	3.126	-5.483	2.588	2.859	-5.016	0.000	0.000	-0.108	0.000	0.000	0.000
34	3.456	3.043	-4.528	3.197	2.815	-4.190	0.000	0.000	-0.108	0.000	0.000	0.000
35	3.947	2.837	-3.473	3.709	2.665	-3.263	0.000	0.000	-0.108	0.000	0.000	0.000
36	4.344	2.665	-2.676	4.036	2.476	-2.486	0.000	0.000	-0.108	0.000	0.000	0.000
37	4.624	2.493	-1.803	4.273	2.304	-1.666	0.000	0.000	-0.108	0.000	0.000	0.000
38	4.722	2.287	-0.962	4.421	2.141	-0.901	0.000	0.000	-0.108	0.000	0.000	0.000
39	4.706	2.149	-0.481	4.476	2.045	-0.457	0.000	0.000	-0.108	0.000	0.000	0.000
40	4.707	1.876	0.731	4.520	1.801	0.702	0.000	0.000	-0.108	0.000	0.000	0.000
41	4.598	1.757	1.387	4.474	1.709	1.350	0.000	0.000	-0.108	0.000	0.000	0.000
42	4.128	0.451	-0.533	4.219	0.461	-0.545	-1.430	0.000	0.095	0.000	0.000	0.000
43	4.297	0.332	0.204	4.276	0.330	0.203	-1.430	0.000	0.095	0.000	0.000	0.000
44	4.098	0.214	0.861	4.137	0.216	0.870	-1.430	0.000	0.095	0.000	0.000	0.000
45	3.900	0.000	-2.335	3.871	0.000	-2.318	-0.462	0.000	0.837	0.000	1.000	-2.000

0 HARNESS NO. 1 BELT NO. 4 FUNCTION NOS. 31 0 0 0 0 REFERENCE SLACK = -0.100 IN.

0 CARDS F.8.D

K	KS	KE	NT	NPD	NDR	FUNCTION NOS.				
46	16	0	421	1	1	0	0	0	0	0
47	1	1	427	0	0	0	0	0	0	33
48	1	1	433	0	0	0	0	0	0	33
49	1	1	439	1	1	0	0	0	0	0

0

K	BASE REFERENCE (IN.) X	Y	Z	ADJUSTED REFERENCE (IN.) X	Y	Z	OFFSET (IN.) X	Y	Z	PREFERRED DIRECTION (IN.) X	Y	Z

46	18.967	0.000	-2.716	18.967	0.000	-2.716	0.000	0.000	0.000	-1.000	0.000	1.000
47	4.479	0.000	0.868	4.518	0.000	0.876	-0.462	0.000	0.837	0.000	0.000	0.000
48	4.497	0.000	-0.832	4.527	0.000	-0.837	-0.462	0.000	0.837	0.000	0.000	0.000
49	3.900	0.000	-2.335	3.871	0.000	-2.318	-0.462	0.000	0.837	0.000	0.000	1.000

CARD G.1

ZPLT(X)	ZPLT(Y)	ZPLT(Z)	I1	J1	I2	J2	I3	SPLT(1)	SPLT(2)	SPLT(3)
0.	0.	0.	0	0	0	0	0	10.00	6.00	1.00

0 INITIAL POSITIONS

CARDS G.2

SEGMENT		LINEAR POSITION (IN.) (IREF4 REFERENCE)			LINEAR VELOCITY (IN./SEC.) (INERTIAL)				
NO.	SEG	X	Y	Z	X	Y	Z	IREF2	IREF4
1	LT	13.88821	0.00001	-15.12504	0.00000	0.00000	0.00000	0	0
2	CT	13.85183	0.00001	-19.63117	0.00000	0.00000	0.00000	0	0
3	UT	11.08807	0.00001	-27.02444	0.00000	0.00000	0.00000	0	0
4	N	10.36620	0.00001	-35.64772	0.00000	0.00000	0.00000	0	0
5	H	11.84088	0.00001	-40.22385	0.00000	0.00000	0.00000	0	0
6	RUL	21.03207	4.54776	-14.13501	0.00000	0.00000	0.00000	0	0
7	RLL	35.84204	6.13372	-9.49290	0.00000	0.00000	0.00000	0	0
8	RF	46.82538	5.69372	-4.69750	0.00000	0.00000	0.00000	0	0
9	LUL	21.03207	-4.54774	-14.13501	0.00000	0.00000	0.00000	0	0
10	LLL	35.84204	-6.13370	-9.49291	0.00000	0.00000	0.00000	0	0
11	LF	46.82538	-5.69370	-4.69751	0.00000	0.00000	0.00000	0	0
12	RUA	10.00782	6.74001	-25.89503	0.00000	0.00000	0.00000	0	0
13	RLA	17.49643	6.04001	-20.35938	0.00000	0.00000	0.00000	0	0
14	LUA	10.00782	-6.73999	-25.89503	0.00000	0.00000	0.00000	0	0
15	LLA	17.49643	-6.03999	-20.35938	0.00000	0.00000	0.00000	0	0

0 INITIAL ANGULAR ROTATION AND VELOCITY

CARDS G.3

SEGMENT		ANGULAR ROTATION (DEG) (IYPR4 REFERENCE)			ANGULAR VELOCITY (DEG/SEC.) (LOCAL)						
NO.	SEG	YAW	PITCH	ROLL	X	Y	Z		IYPR		
1	LT	0.00000	13.00000	0.00000	0.00000	0.00000	0.00000	3	2	1	17
2	CT	0.00000	12.00000	0.00000	0.00000	0.00000	0.00000	3	2	1	17
3	UT	0.00000	10.00000	0.00000	0.00000	0.00000	0.00000	3	2	1	17
4	N	0.00000	5.00000	0.00000	0.00000	0.00000	0.00000	3	2	1	17
5	H	0.00000	3.00000	0.00000	0.00000	0.00000	0.00000	3	2	1	17
6	RUL	4.00000	91.24997	0.00000	0.00000	0.00000	0.00000	3	2	1	17
7	RLL	0.00000	53.40000	0.00000	0.00000	0.00000	0.00000	3	2	1	17
8	RF	0.00000	128.80000	0.00000	0.00000	0.00000	0.00000	3	2	1	17
9	LUL	356.00000	91.25000	0.00000	0.00000	0.00000	0.00000	3	2	1	17
10	LLL	0.00000	53.40000	0.00000	0.00000	0.00000	0.00000	3	2	1	17
11	LF	0.00000	128.80000	0.00000	0.00000	0.00000	0.00000	3	2	1	17
12	RUA	0.00000	12.00000	0.00000	0.00000	0.00000	0.00000	3	2	1	17
13	RLA	0.00000	70.00000	0.00000	0.00000	0.00000	0.00000	3	2	1	12
14	LUA	0.00000	12.00000	0.00000	0.00000	0.00000	0.00000	3	2	1	17
15	LLA	0.00000	70.00000	0.00000	0.00000	0.00000	0.00000	3	2	1	14

0 LINEAR AND ANGULAR VELOCITIES HAVE BEEN SET EQUAL TO THE INITIAL VELOCITIES OF THE PRIMARY VEHICLE FOR ALL NONVEHICLE BODY SEGMENTS WITH IREF2 = 0. FOR NONVEHICLE SEGMENTS WITH IREF2 # 0, THE LINEAR AND ANGULAR VELOCITIES WERE DETERMINED BY THE VALUES OF IREF2.

```
0 HBPLAY TIME =      0.000 MSEC. NH,NB,NPTS NT=     1      1      9    127
  NL(1)=       1       2       3       4       5       6       7       8       9
  BB    =       11.409   2.485   0.979   2.772   2.772   0.974   2.491  11.409
0 HBPLAY TIME =      0.000 MSEC. NH,NB,NPTS NT=     1      2     15    187
  NL(1)=      10      11      12      13      14      15      16      17      18      19      20      21      22      25      27

  BB    =       11.388   0.759   0.790   0.767   1.158   1.024   1.066   0.861   0.868   0.794   0.456   1.181   7.490   2.616

0 HBPLAY TIME =      0.000 MSEC. NH,NB,NPTS NT=     1      3     15    301
  NL(1)=      28      29      30      31      32      33      34      35      36      37      38      39      40      43      45

  BB    =       11.388   0.759   0.790   0.767   1.158   1.024   1.066   0.861   0.868   0.794   0.456   1.181   7.490   2.616

0 HBPLAY TIME =      0.000 MSEC. NH,NB,NPTS NT=     1      4      4    415
  NL(1)=      46      47      48      49
  BB    =       11.598   1.702   1.609

  TABULAR TIME HISTORY CONTROL PARAMETERS
   TYPE  KSG     SELECTED SEGMENTS OR JOINTS
    H. 1   2     -5 -3
       REF        0  0
 NOTE: BEGINNING WITH ATB VERSION IV.3, THE 0 G ACCELEROMETER OPTION IS NOT AVAILABLE.
 ALL ACCELEROMETER OUTPUT USES THE CORRECTED 1 G OPTION.
    H. 2   2       5  3
       REF        0  0
    H. 3   2       5  3
       REF        0  0
    H. 4   2      12 13
       REF        3 12
    H. 5   2      12 13
       REF        3 12
    H. 6   2      12 13
       REF        3 12
    H. 7  14       5  8  6  9  7 10 11 13 12 14  1  2  3  4
       REF        0  0  0  0  0  0  0  0  0  0  0  0  0  0
    H. 8   0
       REF
    H. 9   4       6  7 12 13
       REF        1  6  3 12
1      MAIN3D FUNCTIONS FOR TIME=     0.000 MSEC                                                                          PAGE   28
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SEGMENT	(INERTIAL) ANGULAR ROTATION (DEG) YAW	PITCH	ROLL	(LOCAL) ANGULAR VELOCITY (RAD/SEC.) X	Y	Z	(LOCAL) ANGULAR ACCELERATION (RAD/SEC.**2) X	Y	Z
1 LT	0.0000	13.0000	0.0000	0.00000	0.00000	0.00000	0.000754	-108.367380	-0.000144
2 CT	0.0000	12.0000	0.0000	0.00000	0.00000	0.00000	0.001515	-93.073659	0.000455
3 UT	0.0000	10.0000	0.0000	0.00000	0.00000	0.00000	0.000324	-4.591271	0.000061
4 N	0.0000	5.0000	0.0000	0.00000	0.00000	0.00000	-0.000718	-33.621397	-0.000321
5 H	0.0000	3.0000	0.0000	0.00000	0.00000	0.00000	0.000021	0.627128	0.000012
6 RUL	4.0000	91.2500	0.0000	0.00000	0.00000	0.00000	13.727931	38.957924	45.621124

7	RLL	4.0000	53.4000	0.0000	0.00000	0.00000	0.00000	38.832788	81.606398	27.599957
8	RF	0.0000	128.8000	0.0000	0.00000	0.00000	0.00000	-56.158233	-631.201096	-1065.714628
9	LUL	-4.0000	91.2500	0.0000	0.00000	0.00000	0.00000	-13.730344	38.953972	-45.614259
10	LLL	-4.0000	53.4000	0.0000	0.00000	0.00000	0.00000	-38.830495	81.601117	-27.593035
11	LF	0.0000	128.8000	0.0000	0.00000	0.00000	0.00000	56.147371	-631.174786	1065.732546
12	RUA	0.0000	12.0000	0.0000	0.00000	0.00000	0.00000	-9.741656	32.788555	79.911805
13	RLA	35.6419	74.3765	48.7040	0.00000	0.00000	0.00000	-80.827039	10.653925	13.138360
14	LUA	0.0000	12.0000	0.0000	0.00000	0.00000	0.00000	9.742168	32.788552	-79.911541
15	LLA	-35.6419	74.3765	-48.7040	0.00000	0.00000	0.00000	80.827077	10.653545	-13.137803
16	VEH	0.0000	0.0000	0.0000	0.00000	0.00000	0.00000	0.000000	0.000000	0.000000

SEGMENT		(INERTIAL) LINEAR POSITION (IN.) X	Y	Z	(INERTIAL) LINEAR VELOCITY (IN./SEC.) X	Y	Z	(INERTIAL) LINEAR ACCELERATIONS (G'S) X	Y	Z
1	LT	13.8882	0.0000	-15.1250	0.00000	0.00000	0.00000	-1.776284	-0.000021	1.386971
2	CT	13.8518	0.0000	-19.6312	0.00000	0.00000	0.00000	-0.616402	-0.000005	1.304295
3	UT	11.0881	0.0000	-27.0244	0.00000	0.00000	0.00000	-0.422472	0.000003	0.855277
4	N	10.3662	0.0000	-35.6477	0.00000	0.00000	0.00000	-0.202552	0.000005	0.902845
5	H	11.8409	0.0000	-40.2239	0.00000	0.00000	0.00000	0.018514	0.000000	0.967723
6	RUL	21.0321	4.5478	-14.1350	0.00000	0.00000	0.00000	-2.184621	-0.216649	0.802368
7	RLL	35.7911	6.4920	-9.4929	0.00000	0.00000	0.00000	-1.096815	-1.254587	-1.159668
8	RF	46.8073	6.6116	-4.6975	0.00000	0.00000	0.00000	0.592990	2.033920	1.307914
9	LUL	21.0321	-4.5477	-14.1350	0.00000	0.00000	0.00000	-2.184604	0.216655	0.802402
10	LLL	35.7911	-6.4920	-9.4929	0.00000	0.00000	0.00000	-1.096856	1.254601	-1.159480
11	LF	46.8073	-6.6116	-4.6975	0.00000	0.00000	0.00000	0.592820	-2.033937	1.308005
12	RUA	10.0078	6.7400	-25.8950	0.00000	0.00000	0.00000	0.016380	0.024390	0.791106
13	RLA	17.2186	4.4308	-20.1355	0.00000	0.00000	0.00000	0.924714	1.472720	0.863426
14	LUA	10.0078	-6.7400	-25.8950	0.00000	0.00000	0.00000	0.016380	-0.024385	0.791095
15	LLA	17.2186	-4.4308	-20.1355	0.00000	0.00000	0.00000	0.924713	-1.472721	0.863422
16	VEH	0.0000	0.0000	0.0000	0.00000	0.00000	0.00000	-0.025600	0.000000	0.000000

1

SEGMENT		(INERTIAL) U1 ARRAY (IN./SEC.**2) EXTERNAL LINEAR ACCELERATIONS X	Y	Z	(LOCAL) U2 ARRAY (RAD/SEC.**2) EXTERNAL ANGULAR ACCELERATIONS X	Y	Z	KINETIC ENERGY (LB.- IN.) LINEAR	ANGULAR	TOTAL
1	LT	-0.2351D+04	-0.6008D-02	0.3672D+03	0.60491D-03	-0.36441D+03	-0.10364D-02	0.00000D+00	0.00000D+00	0.00000D+00
2	CT	-0.9171D+02	0.9974D-04	0.4104D+03	-0.26380D-05	-0.71275D+01	0.20044D-04	0.00000D+00	0.00000D+00	0.00000D+00
3	UT	-0.1011D+03	0.1602D-02	0.5282D+03	0.37046D-03	-0.22452D+02	0.73089D-04	0.00000D+00	0.00000D+00	0.00000D+00
4	N	0.0000D+00	0.0000D+00	0.3861D+03	0.00000D+00	0.00000D+00	0.00000D+00	0.00000D+00	0.00000D+00	0.00000D+00
5	H	0.0000D+00	0.0000D+00	0.3861D+03	0.00000D+00	0.00000D+00	0.00000D+00	0.00000D+00	0.00000D+00	0.00000D+00
6	RUL	-0.4773D+02	0.0000D+00	-0.6877D+02	0.21506D+00	0.30986D+03	0.53217D+03	0.00000D+00	0.00000D+00	0.00000D+00
7	RLL	0.0000D+00	0.0000D+00	0.3861D+03	0.30520D+02	0.37934D+02	-0.36763D+02	0.00000D+00	0.00000D+00	0.00000D+00
8	RF	0.8530D-13	-0.2133D-13	-0.6954D+03	-0.50873D+03	-0.12507D+04	-0.20356D+04	0.00000D+00	0.00000D+00	0.00000D+00
9	LUL	-0.4773D+02	0.0000D+00	-0.6875D+02	-0.21503D+00	0.30984D+03	-0.53215D+03	0.00000D+00	0.00000D+00	0.00000D+00
10	LLL	0.0000D+00	0.0000D+00	0.3861D+03	-0.30520D+02	0.37934D+02	0.36763D+02	0.00000D+00	0.00000D+00	0.00000D+00
11	LF	0.0000D+00	0.2133D-13	-0.6952D+03	0.50872D+03	-0.12506D+04	0.20356D+04	0.00000D+00	0.00000D+00	0.00000D+00

12	RUA	0.0000D+00	0.0000D+00	0.3861D+03	-0.75849D+03	0.41957D+03	0.27499D+04	0.00000D+00	0.00000D+00	0.00000D+00
13	RLA	0.0000D+00	0.0000D+00	0.3861D+03	0.00000D+00	0.00000D+00	0.00000D+00	0.00000D+00	0.00000D+00	0.00000D+00
14	LUA	0.0000D+00	0.0000D+00	0.3861D+03	0.75849D+03	0.41957D+03	-0.27499D+04	0.00000D+00	0.00000D+00	0.00000D+00
15	LLA	0.0000D+00	0.0000D+00	0.3861D+03	0.00000D+00	0.00000D+00	0.00000D+00	0.00000D+00	0.00000D+00	0.00000D+00

TOTAL BODY KINETIC ENERGY
0.00000D+00 0.00000D+00 0.00000D+00

		(INERTIAL) JOINT FORCES (LB.)			(INERTIAL) JOINT TORQUES (IN. LB.)			RELATIVE ANGULAR
JOINT	IPIN	X	Y	Z	X	Y	Z	VELOCITY (RAD/SEC.)
1 P	0	-0.288D+01	-0.731D-04	-0.280D+02	0.0000D+00	0.0000D+00	0.0000D+00	0.000
2 W	0	-0.103D+01	-0.497D-04	-0.292D+02	0.0000D+00	0.0000D+00	0.0000D+00	0.000
3 NP	0	-0.270D+00	0.965D-05	-0.510D+00	0.0000D+00	0.0000D+00	0.0000D+00	0.000
4 HP	0	0.171D+00	-0.159D-05	-0.298D+00	0.0000D+00	0.0000D+00	0.0000D+00	0.000
5 RH	0	-0.495D+02	-0.104D+02	0.887D+01	0.0000D+00	0.0000D+00	0.0000D+00	0.000
6 RK	1	-0.759D+01	-0.596D+01	-0.110D+02	-0.2176D+01	-0.1522D+00	0.8423D+01	0.000
7 RA	0	0.119D+01	0.409D+01	0.625D+01	-0.5945D+01	-0.1943D+02	0.1332D+02	0.000
8 LH	0	-0.495D+02	0.104D+02	0.887D+01	0.0000D+00	0.0000D+00	0.0000D+00	0.000
9 LK	1	-0.759D+01	0.596D+01	-0.110D+02	0.2176D+01	-0.1522D+00	-0.8424D+01	0.000
10 LA	0	0.119D+01	-0.409D+01	0.625D+01	0.5945D+01	-0.1943D+02	-0.1332D+02	0.000
11 RS	0	0.369D+01	0.586D+01	-0.137D+01	-0.6689D+02	0.4745D+02	0.7494D+02	0.000
12 RE	1	0.362D+01	0.576D+01	-0.535D+00	-0.6899D+01	0.5526D+01	0.6673D+02	0.000
13 LS	0	0.369D+01	-0.586D+01	-0.137D+01	0.6689D+02	0.4745D+02	-0.7494D+02	0.000
14 LE	1	0.362D+01	-0.576D+01	-0.535D+00	0.6899D+01	0.5526D+01	-0.6673D+02	0.000

1 ELAPSED CPU TIME = 0.79 SECONDS

SUB	CALLS	TIME	%
MAIN3D	1	3	3.80
INPUT	1	3	3.80
CHAIN	2	2	2.53
EJOINT	2	2	2.53
DINTG	1	3	3.80
PDAUX	1	2	2.53
DAUX	1	11	13.92
SETUP1	1	1	1.27
CONTCT	1	23	29.11
PLELP	13	13	16.46
SEGSEG	8	8	10.13
HBELT	1	1	1.27
VISPR	1	1	1.27
SETUP2	1	1	1.27
DAUX11	1	1	1.27
DAUX12	1	1	1.27
DAUX22	1	1	1.27
FSMSOL	1	1	1.27
OUTPUT	1	1	1.27
0TOTAL		79	100.00

POINT NO.	POINT INDEX	SEGMENT NO.	LENGTH (IN.)	BELT STRAIN ENERGY LOSS (IN. LB.)	(LOCAL OR ELLIPSOID) REFERENCE POINT (IN.) X	Y	Z	(INERTIAL) BELT FORCES (LB.) X	Y	Z	PENETRATION ENERGY LOSS (IN. LB.)
0 BELT NO. 1 OF HARNESS NO. 1											
1	1	16	0.000	0.000	7.000	-8.000	-8.500	71.498	18.532	-52.601	0.000
2	2	1	11.409	0.000	2.572	-5.655	-0.381	-39.103	56.235	12.816	0.000
3	3	1	2.485	0.000	3.689	-3.594	-1.249	-23.920	7.942	3.594	0.000
4	4	1	0.979	0.000	3.867	-2.696	-1.611	-13.519	5.007	13.765	0.000
5	5	1	2.772	0.000	3.871	0.000	-2.318	10.088	0.000	44.852	0.000
6	6	1	2.772	0.000	3.867	2.696	-1.611	-13.228	-5.105	14.056	0.000
7	7	1	0.974	0.000	3.692	3.589	-1.247	-24.271	-7.802	3.175	0.000
8	8	1	2.491	0.000	2.572	5.655	-0.381	-39.042	-56.276	12.944	0.000
9	9	16	11.409	0.000	7.000	8.000	-8.500	71.498	-18.532	-52.601	0.000
0 TOTAL BELT ENERGY LOSS				0.000							0.000
0 BELT NO. 2 OF HARNESS NO. 1											
10	10	16	0.000	0.000	-1.500	0.000	-32.000	7.671	-2.170	-0.757	0.000
11	11	3	11.388	0.000	-0.568	-3.098	-6.139	0.156	1.674	-0.860	0.000
12	12	3	0.759	0.000	0.193	-3.143	-6.162	0.174	0.790	1.725	0.000
13	13	3	0.790	0.000	0.970	-3.114	-6.014	-0.288	0.045	2.014	0.000
14	14	3	0.767	0.000	1.665	-3.081	-5.685	-0.647	1.195	1.316	0.000
15	15	3	1.158	0.000	2.588	-2.859	-5.016	-1.272	-1.195	2.077	0.000
16	16	3	1.024	0.000	3.197	-2.815	-4.190	-0.816	0.784	0.654	0.000
17	17	3	1.066	0.000	3.709	-2.665	-3.263	-0.745	0.634	0.396	0.000
18	18	3	0.861	0.000	4.036	-2.476	-2.486	-0.774	-0.177	0.481	0.000
19	19	3	0.868	0.000	4.273	-2.304	-1.666	-0.668	0.061	0.277	0.000
20	20	3	0.794	0.000	4.421	-2.141	-0.901	-0.490	0.046	0.158	0.000
21	21	3	0.456	0.000	4.476	-2.045	-0.457	-0.653	-0.044	0.180	0.000
22	22	3	1.181	0.000	4.520	-1.801	0.702	-0.526	-0.076	0.110	0.000
23	25	2	7.490	0.000	4.276	-0.330	0.203	-0.579	-0.559	0.153	0.000
24	27	1	2.616	0.000	3.871	0.000	-2.318	-0.546	-1.008	-7.926	0.000
0 TOTAL BELT ENERGY LOSS				0.000							0.000
0 BELT NO. 3 OF HARNESS NO. 1											
25	28	16	0.000	0.000	-1.500	0.000	-32.000	7.671	2.170	-0.757	0.000
26	29	3	11.388	0.000	-0.568	3.098	-6.139	0.156	-1.674	-0.860	0.000
27	30	3	0.759	0.000	0.193	3.143	-6.162	0.174	-0.790	1.725	0.000
28	31	3	0.790	0.000	0.970	3.114	-6.014	-0.288	-0.045	2.014	0.000
29	32	3	0.767	0.000	1.665	3.081	-5.685	-0.647	-1.195	1.316	0.000
30	33	3	1.158	0.000	2.588	2.859	-5.016	-1.272	1.195	2.077	0.000
31	34	3	1.024	0.000	3.197	2.815	-4.190	-0.816	-0.784	0.654	0.000
32	35	3	1.066	0.000	3.709	2.665	-3.263	-0.745	-0.634	0.396	0.000
33	36	3	0.861	0.000	4.036	2.476	-2.486	-0.774	0.177	0.481	0.000
34	37	3	0.868	0.000	4.273	2.304	-1.666	-0.668	-0.061	0.277	0.000
35	38	3	0.794	0.000	4.421	2.141	-0.901	-0.490	-0.046	0.158	0.000
36	39	3	0.456	0.000	4.476	2.045	-0.457	-0.653	0.044	0.180	0.000
37	40	3	1.181	0.000	4.520	1.801	0.702	-0.526	0.076	0.110	0.000
38	43	2	7.490	0.000	4.276	0.330	0.203	-0.579	0.559	0.153	0.000
39	45	1	2.616	0.000	3.871	0.000	-2.318	-0.546	1.008	-7.926	0.000

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0    TOTAL BELT ENERGY LOSS              0.000                                                                          0.000
0  BELT NO.    4 OF HARNESS NO.    1
     40       46        16     0.000      0.000     18.967    0.000    -2.716         -1.064     0.000   -16.735         0.000
     41       47         1    11.598      0.000      4.518    0.000     0.876         -2.625     0.000     0.377         0.000
     42       48         1     1.702      0.000      4.527    0.000    -0.837         -6.375     0.001     2.945         0.000
     43       49         1     1.609      0.000      3.871    0.000    -2.318         10.064     0.000    13.414         0.000
0    TOTAL BELT ENERGY LOSS              0.000                                                                          0.000
0 TOTAL HARNESS ENERGY LOSS              0.000                                                                          0.000
1      MAIN3D FUNCTIONS FOR TIME=    10.000 MSEC                                                                       PAGE   31
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SEGMENT	(INERTIAL) ANGULAR ROTATION (DEG) YAW	PITCH	ROLL	(LOCAL) ANGULAR VELOCITY (RAD/SEC.) X	Y	Z	(LOCAL) ANGULAR ACCELERATION (RAD/SEC.**2) X	Y	Z
1 LT	0.0000	13.0696	0.0000	-0.00004	0.15518	-0.00012	-0.693343	-2.545141	-0.054337
2 CT	0.0000	11.9192	0.0000	0.00018	-0.13177	0.00004	-0.072060	11.806965	-0.027780
3 UT	0.0000	10.0178	0.0000	0.00004	0.10488	0.00000	-0.000715	17.020402	0.004136
4 N	0.0000	4.8831	0.0000	-0.00020	-0.39504	0.00038	0.654779	-28.432648	-1.345135
5 H	0.0000	2.9281	0.0000	0.00000	-0.33743	-0.00001	-0.047731	-47.540171	0.076134
6 RUL	0.2804	91.2952	-3.7299	-0.04197	0.11387	0.21961	-2.797903	6.114598	8.022157
7 RLL	4.1231	53.4868	0.1416	0.10146	0.21611	0.19924	2.686471	3.014925	8.063712
8 RF	0.6122	128.4412	0.3147	-0.35091	-0.79716	-0.67797	-0.141073	-5.774660	16.393280
9 LUL	-0.2805	91.2952	3.7298	0.04191	0.11413	-0.21965	3.213156	6.445297	-8.664325
10 LLL	-4.1231	53.4868	-0.1416	-0.10153	0.21600	-0.19924	-2.752107	3.032020	-8.825595
11 LF	-0.6122	128.4412	-0.3146	0.35128	-0.79691	0.67855	0.062925	-6.067241	-16.992997
12 RUA	0.1066	12.1147	-0.0472	-0.25651	0.39654	0.30658	-27.498921	34.958353	20.573705
13 RLA	35.4580	74.4006	48.3838	-0.45902	-0.10754	-0.21000	-37.224875	-13.235123	-25.082567
14 LUA	-0.1066	12.1147	0.0472	0.25651	0.39655	-0.30658	27.499585	34.951803	-20.572336
15 LLA	-35.4580	74.4006	-48.3838	0.45903	-0.10758	0.21000	37.222767	-13.233645	25.082082
16 VEH	0.0000	0.0000	0.0000	0.00000	0.00000	0.00000	0.000000	0.000000	0.000000

SEGMENT	(INERTIAL) LINEAR POSITION (IN.) X	Y	Z	(INERTIAL) LINEAR VELOCITY (IN./SEC.) X	Y	Z	(INERTIAL) LINEAR ACCELERATIONS (G'S) X	Y	Z
1 LT	13.8792	0.0000	-15.1199	-1.14668	-0.00089	0.58041	-0.014885	0.004427	-0.007697
2 CT	13.8443	0.0000	-19.6212	-1.08602	-0.00034	1.11185	-0.083525	0.000038	-0.075835
3 UT	11.0790	0.0000	-27.0167	-1.75160	0.00000	0.97230	-0.403162	-0.000006	0.021777
4 N	10.3581	0.0000	-35.6380	-1.87619	0.00031	1.42284	-0.599891	-0.000560	0.142680
5 H	11.8406	0.0000	-40.2117	-0.18458	0.00018	1.96705	-0.164646	0.000186	0.289055
6 RUL	21.0241	4.5498	-14.1324	-1.06878	0.39411	0.18116	-0.052462	0.068660	-0.090855
7 RLL	35.7903	6.4902	-9.5039	-0.07436	-0.00457	-1.83947	-0.023643	0.076406	-0.266596
8 RF	46.8173	6.6205	-4.7041	1.46995	1.07430	-1.45453	0.036786	-0.032132	-0.291679
9 LUL	21.0241	-4.5497	-14.1324	-1.06926	-0.39523	0.17958	-0.054422	-0.062898	-0.086501
10 LLL	35.7903	-6.4901	-9.5040	-0.07519	0.00446	-1.84300	-0.026858	-0.078205	-0.269235
11 LF	46.8173	-6.6205	-4.7041	1.46818	-1.07554	-1.45808	0.035495	0.033785	-0.293328
12 RUA	10.0074	6.7453	-25.8881	-0.21352	1.16861	0.87311	-0.131299	0.342129	0.026353
13 RLA	17.2328	4.4569	-20.1227	2.56166	5.10064	2.24247	0.464745	1.240863	0.398414
14 LUA	10.0074	-6.7453	-25.8881	-0.21356	-1.16829	0.87265	-0.131244	-0.342186	0.026362
15 LLA	17.2328	-4.4568	-20.1227	2.56162	-5.10032	2.24231	0.464708	-1.240900	0.398396

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 16 VEH      -0.0013    0.0000    0.0000     -0.21880    0.00000    0.00000      -0.019550    0.000000    0.000000
 1                                                                                                        PAGE   32
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SEGMENT		(INERTIAL) U1 ARRAY (IN./SEC.**2) EXTERNAL LINEAR ACCELERATIONS X	Y	Z	(LOCAL) U2 ARRAY (RAD/SEC.**2) EXTERNAL ANGULAR ACCELERATIONS X	Y	Z	KINETIC ENERGY (LB.- IN.) LINEAR	ANGULAR	TOTAL
1	LT	-0.7746D+03	0.2856D+01	-0.1721D+04	-0.93077D+00	-0.31792D+03	-0.23110D+00	0.50476D-01	0.93193D-02	0.59796D-01
2	CT	-0.5962D+02	0.7354D-03	0.3123D+03	-0.79605D-01	0.24253D+03	-0.27230D-01	0.15241D-01	0.63988D-03	0.15881D-01
3	UT	-0.1369D+03	0.2199D-02	0.5373D+03	-0.94227D-03	-0.13207D+02	0.43499D-02	0.26295D+00	0.16480D-01	0.27943D+00
4	N	0.0000D+00	0.0000D+00	0.3861D+03	0.10030D+01	0.10953D+04	-0.12466D+01	0.15646D-01	0.13655D-02	0.17012D-01
5	H	0.0000D+00	0.0000D+00	0.3861D+03	-0.25339D-01	-0.96670D+01	0.88961D-01	0.46688D-01	0.11665D-01	0.58353D-01
6	RUL	0.3316D+03	0.1882D+02	-0.1043D+03	-0.17040D+02	0.54802D+03	0.39239D+03	0.34999D-01	0.22299D-02	0.37229D-01
7	RLL	0.0000D+00	0.0000D+00	0.3861D+03	-0.55065D+01	-0.19731D+01	-0.63916D+02	0.35148D-01	0.15343D-01	0.50492D-01
8	RF	0.7042D+03	0.4526D+03	-0.3526D+03	0.20594D+03	-0.43323D+01	0.50352D+03	0.14136D-01	0.12845D-01	0.26981D-01
9	LUL	0.3312D+03	-0.1812D+02	-0.1042D+03	0.16547D+02	0.54771D+03	-0.39902D+03	0.35034D-01	0.22370D-02	0.37271D-01
10	LLL	0.0000D+00	0.0000D+00	0.3861D+03	0.55314D+01	-0.19478D+01	0.63845D+02	0.35285D-01	0.15335D-01	0.50620D-01
11	LF	0.7046D+03	-0.4529D+03	-0.3524D+03	-0.20647D+03	-0.41152D+01	-0.50511D+03	0.14156D-01	0.12843D-01	0.26999D-01
12	RUA	0.0000D+00	0.0000D+00	0.3861D+03	-0.69155D+03	0.24969D+03	0.17587D+04	0.11310D-01	0.13421D-01	0.24731D-01
13	RLA	0.0000D+00	0.0000D+00	0.3861D+03	0.93643D+01	0.34955D+02	0.44563D-02	0.19062D+00	0.28848D-01	0.21947D+00
14	LUA	0.0000D+00	0.0000D+00	0.3861D+03	0.69158D+03	0.24968D+03	-0.17587D+04	0.11302D-01	0.13421D-01	0.24723D-01
15	LLA	0.0000D+00	0.0000D+00	0.3861D+03	-0.93651D+01	0.34958D+02	-0.44581D-02	0.19060D+00	0.28850D-01	0.21945D+00
								TOTAL BODY KINETIC ENERGY		
								0.96360D+00	0.18484D+00	0.11484D+01

JOINT		IPIN	(INERTIAL) JOINT FORCES (LB.) X	Y	Z	(INERTIAL) JOINT TORQUES (IN. LB.) X	Y	Z	RELATIVE ANGULAR VELOCITY (RAD/SEC.)
1	P	0	-0.236D+01	-0.267D-03	-0.946D+02	-0.7289D-02	0.8221D+01	-0.3091D-02	0.287
2	W	0	-0.270D+01	-0.445D-03	-0.903D+02	0.4241D-02	-0.6780D+01	0.9366D-04	0.237
3	NP	0	-0.283D+01	0.502D-03	-0.843D+01	0.6789D-02	0.1719D+02	-0.1395D-01	0.500
4	HP	0	-0.152D+01	0.172D-02	-0.657D+01	-0.5413D-02	-0.1981D+01	0.1412D-01	0.058
5	RH	0	-0.223D+02	-0.140D+01	-0.525D+01	-0.3645D+01	0.4508D+00	-0.6408D+00	0.217
6	RK	1	-0.378D+01	-0.181D+01	-0.889D+01	0.1886D+02	-0.4005D+00	-0.2681D+02	0.102
7	RA	0	-0.359D+01	-0.242D+01	0.125D+01	0.4592D+01	-0.4594D+00	-0.3316D-01	1.325
8	LH	0	-0.223D+02	0.148D+01	-0.519D+01	0.3643D+01	0.4463D+00	0.6361D+00	0.217
9	LK	1	-0.381D+01	0.180D+01	-0.892D+01	-0.1887D+02	-0.3932D+00	0.2678D+02	0.102
10	LA	0	-0.360D+01	0.243D+01	0.125D+01	-0.4596D+01	-0.4655D+00	0.4545D-01	1.326
11	RS	0	0.129D+01	0.623D+01	-0.627D+01	-0.6198D+02	0.3710D+02	0.5211D+02	0.495
12	RE	1	0.182D+01	0.486D+01	-0.235D+01	-0.2134D+01	0.1271D+02	0.4499D+02	0.539
13	LS	0	0.129D+01	-0.623D+01	-0.627D+01	0.6198D+02	0.3710D+02	-0.5211D+02	0.495
14	LE	1	0.182D+01	-0.486D+01	-0.235D+01	0.2133D+01	0.1271D+02	-0.4499D+02	0.539

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1 ELAPSED CPU TIME =      37.20 SECONDS                                                             PAGE   33

     SUB         CALLS        TIME        %
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MAIN3D	1	9	0.24
INPUT	1	3	0.08
CHAIN	52	52	1.40
EJOINT	52	52	1.40
DINTG	6	137	3.68
PDAUX	63	114	3.06
DAUX	51	561	15.08
SETUP1	51	51	1.37
CONTCT	51	1173	31.53
PLELP	663	663	17.82
SEGSEG	408	408	10.97
HBELT	63	63	1.69
VISPR	51	51	1.37
SETUP2	51	51	1.37
DAUX11	51	51	1.37
DAUX12	51	51	1.37
DAUX22	51	51	1.37
FSMSOL	63	63	1.69
OUTPUT	6	6	0.16
UPDATE	12	24	0.65
HPTURB	12	36	0.97
DZP	50	50	1.34
0TOTAL		3720	100.00

1 HARNESS BELT RESULTS FOR TIME = 10.000 MSEC.

POINT NO.	POINT INDEX	SEGMENT NO.	LENGTH (IN.)	BELT STRAIN ENERGY LOSS (IN. LB.)	(LOCAL OR ELLIPSOID) REFERENCE POINT (IN.) X	Y	Z	(INERTIAL) BELT FORCES (LB.) X	Y	Z	PENETRATION ENERGY LOSS (IN. LB.)
0 BELT NO.	1 OF HARNESS NO. 1										
1	1	16	0.000	0.000	7.000	-8.000	-8.500	64.034	16.611	-47.132	0.000
2	2	1	11.408	0.000	2.572	-5.655	-0.381	-33.451	54.078	9.480	0.000
3	3	1	2.486	0.000	3.689	-3.594	-1.249	-22.247	11.088	1.859	0.000
4	4	1	0.979	0.000	3.867	-2.696	-1.611	-13.407	5.938	13.373	0.000
5	5	1	2.772	0.000	3.871	0.000	-2.318	10.142	0.000	44.840	0.000
6	6	1	2.772	0.000	3.867	2.696	-1.611	-13.120	-6.031	13.663	0.000
7	7	1	0.974	0.000	3.692	3.589	-1.247	-22.596	-10.945	1.454	0.000
8	8	1	2.492	0.000	2.572	5.655	-0.381	-33.396	-54.126	9.600	0.000
9	9	16	11.408	0.000	7.000	8.000	-8.500	64.041	-16.613	-47.137	0.000
0 TOTAL BELT ENERGY LOSS				0.000							0.000
0 BELT NO.	2 OF HARNESS NO. 1										
10	10	16	0.000	0.000	-1.500	0.000	-32.000	7.884	-2.260	-0.754	0.000
11	11	3	11.383	0.000	-0.575	-3.138	-6.112	3.763	2.114	-2.056	0.000
12	12	3	0.765	0.000	0.193	-3.143	-6.162	-3.644	0.440	2.915	0.000
13	13	3	0.790	0.000	0.970	-3.114	-6.014	-0.287	0.045	2.014	0.000
14	14	3	0.767	0.000	1.665	-3.081	-5.685	-0.646	1.195	1.316	0.000
15	15	3	1.158	0.000	2.588	-2.859	-5.016	-1.271	-1.195	2.078	0.000
16	16	3	1.024	0.000	3.197	-2.815	-4.190	-0.816	0.784	0.655	0.000
17	17	3	1.066	0.000	3.709	-2.665	-3.263	-0.745	0.634	0.396	0.000
18	18	3	0.861	0.000	4.036	-2.476	-2.486	-0.774	-0.177	0.481	0.000

	19	19	3	0.868	0.000	4.273	-2.304	-1.666	-0.667	0.061	0.277	0.000
	20	20	3	0.794	0.000	4.421	-2.141	-0.901	-0.490	0.046	0.158	0.000
	21	21	3	0.456	0.000	4.476	-2.045	-0.457	-0.652	-0.044	0.180	0.000
	22	22	3	1.181	0.000	4.520	-1.801	0.702	-0.542	-0.098	0.009	0.000
	23	25	2	7.500	0.000	4.276	-0.330	0.203	-0.872	-1.092	-4.123	0.000
	24	27	1	2.606	0.000	3.871	0.000	-2.318	-0.239	-0.453	-3.547	0.000
0	TOTAL BELT ENERGY LOSS				0.000							0.000
0	BELT NO. 3 OF HARNESS NO. 1											
	25	28	16	0.000	0.000	-1.500	0.000	-32.000	7.884	2.260	-0.754	0.000
	26	29	3	11.382	0.000	-0.575	3.138	-6.112	3.762	-2.114	-2.056	0.000
	27	30	3	0.765	0.000	0.193	3.143	-6.162	-3.643	-0.440	2.915	0.000
	28	31	3	0.790	0.000	0.970	3.114	-6.014	-0.287	-0.045	2.014	0.000
	29	32	3	0.767	0.000	1.665	3.081	-5.685	-0.646	-1.195	1.316	0.000
	30	33	3	1.158	0.000	2.588	2.859	-5.016	-1.271	1.195	2.078	0.000
	31	34	3	1.024	0.000	3.197	2.815	-4.190	-0.816	-0.784	0.655	0.000
	32	35	3	1.066	0.000	3.709	2.665	-3.263	-0.745	-0.634	0.396	0.000
	33	36	3	0.861	0.000	4.036	2.476	-2.486	-0.774	0.177	0.481	0.000
	34	37	3	0.868	0.000	4.273	2.304	-1.666	-0.667	-0.061	0.277	0.000
	35	38	3	0.794	0.000	4.421	2.141	-0.901	-0.490	-0.046	0.158	0.000
	36	39	3	0.456	0.000	4.476	2.045	-0.457	-0.652	0.044	0.180	0.000
	37	40	3	1.181	0.000	4.520	1.801	0.702	-0.542	0.098	0.009	0.000
	38	43	2	7.500	0.000	4.276	0.330	0.203	-0.872	1.092	-4.123	0.000
	39	45	1	2.606	0.000	3.871	0.000	-2.318	-0.239	0.453	-3.548	0.000
0	TOTAL BELT ENERGY LOSS				0.000							0.000
0	BELT NO. 4 OF HARNESS NO. 1											
	40	46	16	0.000	0.000	18.967	0.000	-2.716	-1.082	0.000	-16.858	0.000
	41	47	1	11.598	0.000	4.518	0.000	0.876	-2.627	0.000	0.504	0.000
	42	48	1	1.702	0.000	4.527	0.000	-0.837	-6.371	0.001	2.952	0.000
	43	49	1	1.609	0.000	3.871	0.000	-2.318	10.080	0.000	13.402	0.000
0	TOTAL BELT ENERGY LOSS				0.000							0.000
0	TOTAL HARNESS ENERGY LOSS				0.000							0.000

Example Time History Files

Time history files are those files with output logical units greater than 21. The data in time history files are arranged in columns. These column data can be easily ported to any spreadsheet or graphics software for further result analysis. There are a total of 33 time history files, from example.t21 up to example.t53, being generated by using example.ain as the ATB input file. In this section, only one file for each type of time history output is presented. The included files are:

1. Example.t21: Point linear accelerations.
2. Example.t22: Point linear velocities.
3. Example.t23: Point linear positions.
4. Example.t24: Point angular accelerations.
5. Example.t25: Point angular velocities.
6. Example.t26: Point angular positions.
7. Example.t27: Joint parameters.
8. Example.t37: Joint forces and torques.
9. Example.t38: Plane/segment contacts.
10. Example.t45: Harness belt contacts.
11. Example.t47: Ellipsoid/ellipsoid contacts.

Each file's output unit is shown by the highlighted file page number.

1

DATE: 21 FEB 1995
RUN DESCRIPTION: SIMULATION OF THE HUMAN VOLUNTEER SLED TEST
USING NEWLY DEVELOPED HUMAN JOINT CHARACTERISTICS
VEHICLE DECELERATION: SLED ACCELERATION
CRASH VICTIM: MALE HUMAN 167 LB

POINT TOTAL ACCELERATION (G'S)

TIME (MSEC)	POINT (6.20, 0.00, 3.22) ON SEGMENT NO. -5 - H ACCELEROMETER (1G)				POINT (4.74, 0.00, 0.00) ON SEGMENT NO. -3 - UT ACCELEROMETER (1G)			
	X	Y	Z	RES	X	Y	Z	RES
0.000	0.025	0.000	-0.041	0.049	-0.391	0.000	-0.160	0.422
2.000	-0.085	0.000	-0.039	0.094	-0.407	0.000	-0.646	0.764
4.000	-0.276	0.000	0.046	0.280	-0.320	0.000	-1.025	1.074
6.000	-0.415	0.000	0.098	0.427	-0.274	0.000	-1.175	1.207
8.000	-0.493	0.000	0.094	0.502	-0.249	0.000	-1.221	1.246
10.000	-0.526	0.002	0.044	0.528	-0.227	0.000	-1.242	1.263
12.000	-0.538	0.000	-0.026	0.538	-0.210	0.000	-1.241	1.259
14.000	-0.535	0.001	-0.109	0.546	-0.194	0.000	-1.233	1.248
16.000	-0.525	0.000	-0.191	0.559	-0.179	0.000	-1.215	1.228
18.000	-0.513	0.001	-0.272	0.581	-0.166	0.000	-1.205	1.216
20.000	-0.357	0.002	-0.551	0.656	-0.061	0.000	-1.120	1.121
22.000	-0.319	0.001	-0.631	0.707	-0.051	0.000	-1.115	1.116
24.000	-0.188	0.000	-0.866	0.887	0.055	0.000	-1.008	1.010
26.000	-0.107	0.001	-0.970	0.976	0.067	0.000	-1.014	1.016
28.000	-0.067	0.000	-1.022	1.024	0.085	0.000	-1.013	1.017
30.000	-0.046	0.000	-1.046	1.047	0.097	0.000	-1.020	1.025
32.000	-0.039	0.000	-1.053	1.053	0.107	0.000	-1.015	1.021
34.000	-0.023	0.000	-1.071	1.071	0.122	0.000	-1.001	1.008
36.000	-0.005	0.000	-1.091	1.091	0.138	0.000	-0.998	1.007
38.000	0.000	0.000	-1.088	1.088	0.142	0.000	-1.006	1.016
40.000	-0.003	0.000	-1.078	1.078	0.146	0.000	-1.002	1.013
42.000	-0.005	0.000	-1.068	1.068	0.159	0.000	-1.001	1.014
44.000	-0.006	0.000	-1.062	1.062	0.175	0.000	-1.002	1.017
46.000	-0.004	0.000	-1.061	1.061	0.187	0.000	-1.001	1.018
48.000	0.002	0.000	-1.066	1.066	0.194	0.000	-0.996	1.015
50.000	0.009	0.000	-1.073	1.073	0.200	0.000	-0.992	1.012
52.000	0.016	0.000	-1.076	1.076	0.201	0.000	-0.977	0.998
54.000	0.005	0.000	-1.038	1.038	0.189	0.000	-0.954	0.973
56.000	-0.011	0.000	-1.018	1.018	0.181	0.000	-1.006	1.022
58.000	0.057	0.000	-1.160	1.162	0.214	0.000	-1.003	1.026
60.000	0.138	0.000	-1.286	1.293	0.235	0.000	-0.975	1.003
62.000	0.202	0.000	-1.347	1.362	0.220	0.000	-0.916	0.942
64.000	0.230	0.000	-1.348	1.368	0.129	0.000	-0.904	0.913
66.000	0.195	0.000	-1.278	1.292	-0.010	0.000	-0.933	0.933
68.000	0.218	0.000	-1.308	1.326	-0.052	0.000	-0.890	0.892
70.000	0.267	0.000	-1.352	1.378	-0.107	0.000	-0.837	0.843
72.000	0.324	0.000	-1.387	1.424	-0.174	-0.001	-0.743	0.763
74.000	0.399	0.000	-1.458	1.512	-0.221	0.000	-0.752	0.784
76.000	0.477	0.000	-1.517	1.591	-0.288	0.001	-0.686	0.744

DATE: 21 FEB 1995
RUN DESCRIPTION: SIMULATION OF THE HUMAN VOLUNTEER SLED TEST
USING NEWLY DEVELOPED HUMAN JOINT CHARACTERISTICS
VEHICLE DECELERATION: SLED ACCELERATION
CRASH VICTIM: MALE HUMAN 167 LB

CARD A2
CARD A2 **PAGE: 22.00**
CARD C1

POINT REL. VELOCITY (IN./SEC.)

TIME (MSEC)	POINT (6.20, 0.00, 3.22) ON SEGMENT NO. 5 - H IN VEH REFERENCE X	Y	Z	RES	POINT (4.74, 0.00, 0.00) ON SEGMENT NO. 3 - UT IN VEH REFERENCE X	Y	Z	RES
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2.000	0.013	0.000	0.781	0.781	-0.318	0.000	0.638	0.713
4.000	-0.057	0.000	1.559	1.560	-0.640	0.000	0.790	1.017
6.000	-0.251	0.000	2.400	2.414	-0.949	0.000	0.742	1.205
8.000	-0.564	-0.001	3.264	3.313	-1.281	-0.001	0.623	1.424
10.000	-0.943	0.000	4.112	4.219	-1.619	0.000	0.483	1.690
12.000	-1.333	0.000	4.911	5.089	-1.935	0.000	0.335	1.964
14.000	-1.727	0.001	5.651	5.909	-2.238	0.000	0.190	2.246
16.000	-2.131	0.001	6.327	6.676	-2.538	0.000	0.053	2.538
18.000	-2.535	0.001	6.938	7.387	-2.831	0.000	-0.076	2.832
20.000	-2.847	0.001	7.356	7.888	-3.019	0.000	-0.138	3.022
22.000	-3.096	0.002	7.684	8.284	-3.186	0.000	-0.213	3.193
24.000	-3.269	0.002	7.908	8.557	-3.275	0.000	-0.251	3.285
26.000	-3.357	0.002	7.970	8.648	-3.319	0.001	-0.257	3.329
28.000	-3.442	0.002	7.973	8.684	-3.390	0.001	-0.268	3.401
30.000	-3.512	0.002	7.941	8.683	-3.459	0.001	-0.280	3.471
32.000	-3.567	0.003	7.905	8.672	-3.515	0.001	-0.296	3.527
34.000	-3.606	0.003	7.858	8.646	-3.553	0.001	-0.304	3.566
36.000	-3.641	0.003	7.794	8.602	-3.589	0.001	-0.307	3.602
38.000	-3.664	0.003	7.721	8.546	-3.617	0.001	-0.314	3.630
40.000	-3.679	0.003	7.658	8.496	-3.635	0.002	-0.323	3.649
42.000	-3.679	0.003	7.602	8.445	-3.632	0.002	-0.331	3.647
44.000	-3.670	0.003	7.552	8.397	-3.610	0.002	-0.341	3.626
46.000	-3.661	0.003	7.505	8.350	-3.578	0.002	-0.354	3.595
48.000	-3.656	0.003	7.456	8.304	-3.547	0.002	-0.366	3.566
50.000	-3.634	0.003	7.402	8.246	-3.501	0.003	-0.376	3.521
52.000	-3.567	0.003	7.343	8.164	-3.414	0.003	-0.380	3.435
54.000	-3.465	0.003	7.300	8.080	-3.289	0.003	-0.362	3.309
56.000	-3.338	0.003	7.284	8.013	-3.148	0.004	-0.348	3.167
58.000	-3.161	0.003	7.218	7.880	-2.957	0.004	-0.367	2.980
60.000	-2.794	0.003	7.044	7.578	-2.622	0.004	-0.377	2.649
62.000	-2.072	0.003	6.801	7.109	-1.977	0.004	-0.347	2.008
64.000	-0.841	0.003	6.531	6.585	-0.895	0.005	-0.285	0.940
66.000	0.762	0.003	6.286	6.332	0.457	0.004	-0.232	0.512
68.000	2.534	0.004	6.058	6.567	1.925	0.005	-0.150	1.931
70.000	4.531	0.000	5.800	7.360	3.555	0.000	-0.019	3.555
72.000	6.779	0.003	5.505	8.733	5.354	0.003	0.167	5.357
74.000	9.335	-0.007	5.205	10.688	7.368	-0.007	0.439	7.381
76.000	12.348	-0.016	4.824	13.257	9.739	-0.016	0.718	9.765

1

DATE: 21 FEB 1995
RUN DESCRIPTION: SIMULATION OF THE HUMAN VOLUNTEER SLED TEST
USING NEWLY DEVELOPED HUMAN JOINT CHARACTERISTICS
VEHICLE DECELERATION: SLED ACCELERATION
CRASH VICTIM: MALE HUMAN 167 LB

CARD A2
CARD A2 **PAGE: 23.00**
CARD C1

POINT REL. LINEAR DISPLACEMENT (IN.)

TIME	POINT (6.20, 0.00, 3.22) ON SEGMENT NO. 5 - H IN VEH REFERENCE				POINT (4.74, 0.00, 0.00) ON SEGMENT NO. 3 - UT IN VEH REFERENCE			
(MSEC)	X	Y	Z	RES	X	Y	Z	RES
0.000	18.201	0.000	-37.335	41.535	15.754	0.000	-27.847	31.995
2.000	18.201	0.000	-37.334	41.534	15.754	0.000	-27.846	31.994
4.000	18.201	0.000	-37.332	41.532	15.753	0.000	-27.845	31.992
6.000	18.201	0.000	-37.328	41.528	15.751	0.000	-27.843	31.990
8.000	18.200	0.000	-37.322	41.523	15.749	0.000	-27.842	31.988
10.000	18.198	0.000	-37.315	41.516	15.746	0.000	-27.841	31.985
12.000	18.196	0.000	-37.306	41.507	15.743	0.000	-27.840	31.983
14.000	18.193	0.000	-37.295	41.496	15.738	0.000	-27.840	31.980
16.000	18.189	0.000	-37.283	41.483	15.734	0.000	-27.839	31.978
18.000	18.184	0.000	-37.270	41.469	15.728	0.000	-27.839	31.975
20.000	18.179	0.000	-37.255	41.454	15.722	0.000	-27.840	31.972
22.000	18.173	0.000	-37.240	41.438	15.716	0.000	-27.840	31.970
24.000	18.167	0.000	-37.225	41.421	15.710	0.000	-27.840	31.967
26.000	18.160	0.000	-37.209	41.404	15.703	0.000	-27.841	31.964
28.000	18.153	0.000	-37.193	41.387	15.696	0.000	-27.841	31.961
30.000	18.146	0.000	-37.177	41.369	15.690	0.000	-27.842	31.958
32.000	18.139	0.000	-37.161	41.352	15.683	0.000	-27.843	31.955
34.000	18.132	0.000	-37.145	41.335	15.675	0.000	-27.843	31.952
36.000	18.125	0.000	-37.130	41.317	15.668	0.000	-27.844	31.950
38.000	18.117	0.000	-37.114	41.300	15.661	0.000	-27.844	31.947
40.000	18.110	0.000	-37.099	41.283	15.654	0.000	-27.845	31.944
42.000	18.103	0.000	-37.084	41.266	15.647	0.000	-27.846	31.941
44.000	18.095	0.000	-37.068	41.249	15.639	0.000	-27.846	31.938
46.000	18.088	0.000	-37.053	41.233	15.632	0.000	-27.847	31.935
48.000	18.081	0.000	-37.038	41.216	15.625	0.000	-27.848	31.932
50.000	18.073	0.000	-37.024	41.199	15.618	0.000	-27.849	31.929
52.000	18.066	0.000	-37.009	41.183	15.611	0.000	-27.849	31.926
54.000	18.059	0.000	-36.994	41.167	15.604	0.000	-27.850	31.924
56.000	18.052	0.000	-36.980	41.151	15.598	0.000	-27.851	31.921
58.000	18.046	0.000	-36.965	41.135	15.592	0.000	-27.851	31.919
60.000	18.040	0.000	-36.951	41.119	15.586	0.000	-27.852	31.917
62.000	18.035	0.000	-36.937	41.105	15.581	0.000	-27.853	31.915
64.000	18.032	0.000	-36.924	41.091	15.579	0.000	-27.854	31.914
66.000	18.032	0.000	-36.911	41.080	15.578	0.000	-27.854	31.914
68.000	18.035	0.000	-36.898	41.070	15.580	0.000	-27.854	31.916
70.000	18.042	0.000	-36.887	41.063	15.586	0.000	-27.855	31.919
72.000	18.053	0.000	-36.875	41.057	15.595	0.000	-27.854	31.923
74.000	18.069	0.000	-36.865	41.055	15.607	0.000	-27.854	31.929
76.000	18.091	0.000	-36.854	41.055	15.624	0.000	-27.853	31.936

1

DATE: 21 FEB 1995
RUN DESCRIPTION: SIMULATION OF THE HUMAN VOLUNTEER SLED TEST
USING NEWLY DEVELOPED HUMAN JOINT CHARACTERISTICS
VEHICLE DECELERATION: SLED ACCELERATION
CRASH VICTIM: MALE HUMAN 167 LB

CARD A2
CARD A2 **PAGE: 24.00**
CARD C1

SEGMENT ANGULAR ACCELERATION (REV/SEC.**2)

TIME	SEGMENT NO. 12 - RUA IN UT REFERENCE				SEGMENT NO. 13 - RLA IN RUA REFERENCE			
(MSEC)	X	Y	Z	RES	X	Y	Z	RES
0.000	-1.106	5.218	12.765	13.834	-3.189	-0.897	12.718	13.143
2.000	-3.983	6.802	5.279	9.487	-6.407	-1.571	5.137	8.361
4.000	-4.105	6.719	4.635	9.136	-6.709	-2.430	4.493	8.432
6.000	-4.199	6.388	4.136	8.691	-6.711	-2.510	3.997	8.205
8.000	-4.252	5.970	3.743	8.230	-6.566	-2.266	3.611	7.828
10.000	-4.264	5.560	3.426	7.799	-6.372	-1.986	3.304	7.448
12.000	-4.239	5.136	3.173	7.377	-6.140	-1.706	3.065	7.071
14.000	-4.185	4.719	2.968	6.970	-5.891	-1.461	2.875	6.716
16.000	-4.108	4.311	2.799	6.580	-5.625	-1.218	2.723	6.367
18.000	-4.012	3.959	2.653	6.229	-5.371	-1.037	2.595	6.054
20.000	-3.879	2.597	2.671	5.378	-4.905	-1.160	2.625	5.682
22.000	-3.767	2.351	2.524	5.108	-4.686	-1.055	2.494	5.413
24.000	-3.614	0.944	2.589	4.545	-4.201	-1.206	2.567	5.069
26.000	-3.496	0.778	2.434	4.330	-4.026	-1.199	2.424	4.850
28.000	-3.369	0.569	2.308	4.123	-3.832	-1.188	2.310	4.629
30.000	-3.240	0.452	2.181	3.932	-3.660	-1.180	2.196	4.428
32.000	-3.107	0.315	2.076	3.750	-3.473	-1.146	2.103	4.218
34.000	-2.970	0.113	1.993	3.578	-3.270	-1.126	2.030	4.010
36.000	-2.831	-0.049	1.911	3.416	-3.086	-1.137	1.958	3.828
38.000	-2.696	-0.059	1.810	3.248	-2.940	-1.135	1.869	3.664
40.000	-2.561	-0.114	1.728	3.092	-2.777	-1.111	1.798	3.490
42.000	-2.428	-0.194	1.656	2.946	-2.607	-1.071	1.736	3.310
44.000	-2.296	-0.271	1.588	2.805	-2.442	-1.047	1.677	3.142
46.000	-2.166	-0.342	1.523	2.670	-2.287	-1.044	1.621	2.992
48.000	-2.036	-0.405	1.461	2.539	-2.141	-1.059	1.568	2.857
50.000	-1.908	-0.462	1.403	2.413	-2.000	-1.085	1.518	2.736
52.000	-1.991	-0.660	0.417	2.139	-1.148	2.045	0.526	2.404
54.000	-3.176	-1.592	-6.613	7.507	5.617	29.794	-6.635	31.037
56.000	-2.558	-1.283	-6.874	7.446	8.382	38.287	-6.951	39.805
58.000	-0.324	-0.129	0.012	0.348	4.396	17.478	0.006	18.022
60.000	1.056	0.876	5.072	5.254	-0.595	-4.494	5.163	6.871
62.000	0.746	0.634	4.582	4.685	-1.416	-6.734	4.667	8.314
64.000	0.374	0.777	3.583	3.685	-1.667	-6.383	3.675	7.551
66.000	0.130	1.226	2.781	3.042	-1.914	-6.207	2.904	7.115
68.000	-0.020	0.700	2.343	2.446	-1.869	-6.060	2.453	6.800
70.000	-0.124	0.235	1.998	2.016	-1.790	-5.885	2.096	6.498
72.000	-0.206	-0.267	1.733	1.765	-1.655	-5.592	1.814	6.107
74.000	-0.208	-0.690	1.533	1.694	-1.582	-5.741	1.603	6.167
76.000	-0.212	-1.259	1.386	1.884	-1.441	-5.734	1.432	6.083

1

DATE: 21 FEB 1995
RUN DESCRIPTION: SIMULATION OF THE HUMAN VOLUNTEER SLED TEST
USING NEWLY DEVELOPED HUMAN JOINT CHARACTERISTICS
VEHICLE DECELERATION: SLED ACCELERATION
CRASH VICTIM: MALE HUMAN 167 LB

CARD A2
CARD A2 **PAGE: 25.00**
CARD C1

SEGMENT REL. ANGULAR VELOCITY (REV/SEC.)

TIME	SEGMENT NO. 12 - RUA				SEGMENT NO. 13 - RLA			
	IN UT REFERENCE				IN RUA REFERENCE			
(MSEC)	X	Y	Z	RES	X	Y	Z	RES
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2.000	-0.006	0.013	0.017	0.022	-0.004	-0.013	0.000	0.014
4.000	-0.014	0.024	0.026	0.039	-0.008	-0.031	0.000	0.032
6.000	-0.022	0.033	0.035	0.053	-0.013	-0.050	0.000	0.051
8.000	-0.031	0.040	0.043	0.066	-0.018	-0.067	0.000	0.069
10.000	-0.039	0.046	0.050	0.079	-0.022	-0.083	0.000	0.086
12.000	-0.048	0.052	0.057	0.090	-0.026	-0.097	0.000	0.101
14.000	-0.056	0.057	0.063	0.101	-0.030	-0.111	0.000	0.114
16.000	-0.064	0.061	0.069	0.112	-0.033	-0.122	0.000	0.127
18.000	-0.073	0.064	0.074	0.122	-0.036	-0.133	0.000	0.138
20.000	-0.080	0.068	0.079	0.132	-0.038	-0.141	0.000	0.146
22.000	-0.088	0.071	0.085	0.141	-0.040	-0.148	0.000	0.153
24.000	-0.096	0.073	0.090	0.150	-0.041	-0.154	0.000	0.159
26.000	-0.103	0.075	0.095	0.159	-0.042	-0.158	0.000	0.163
28.000	-0.110	0.077	0.099	0.167	-0.043	-0.162	0.000	0.167
30.000	-0.116	0.079	0.104	0.175	-0.044	-0.165	0.000	0.171
32.000	-0.123	0.080	0.108	0.182	-0.045	-0.168	0.000	0.174
34.000	-0.129	0.081	0.112	0.189	-0.046	-0.171	0.000	0.177
36.000	-0.135	0.082	0.116	0.195	-0.046	-0.173	0.000	0.179
38.000	-0.140	0.082	0.119	0.202	-0.047	-0.175	0.000	0.181
40.000	-0.146	0.082	0.123	0.208	-0.047	-0.177	0.000	0.183
42.000	-0.151	0.082	0.126	0.213	-0.048	-0.179	0.000	0.185
44.000	-0.155	0.082	0.129	0.218	-0.048	-0.180	0.000	0.187
46.000	-0.160	0.081	0.132	0.223	-0.049	-0.182	0.000	0.188
48.000	-0.164	0.080	0.135	0.228	-0.049	-0.183	0.000	0.190
50.000	-0.168	0.080	0.138	0.232	-0.049	-0.184	0.000	0.191
52.000	-0.172	0.079	0.141	0.236	-0.050	-0.185	0.000	0.192
54.000	-0.178	0.076	0.133	0.235	-0.040	-0.149	0.000	0.154
56.000	-0.184	0.073	0.119	0.230	-0.020	-0.074	0.000	0.077
58.000	-0.187	0.071	0.111	0.229	-0.003	-0.013	0.000	0.013
60.000	-0.186	0.075	0.117	0.232	-0.001	-0.004	0.000	0.004
62.000	-0.184	0.080	0.127	0.237	-0.005	-0.018	0.000	0.019
64.000	-0.183	0.086	0.135	0.243	-0.009	-0.032	0.000	0.033
66.000	-0.182	0.093	0.141	0.249	-0.012	-0.046	0.000	0.048
68.000	-0.182	0.102	0.146	0.255	-0.016	-0.060	0.000	0.063
70.000	-0.182	0.112	0.151	0.262	-0.020	-0.073	0.000	0.076
72.000	-0.183	0.123	0.154	0.269	-0.023	-0.085	0.000	0.088
74.000	-0.183	0.135	0.158	0.277	-0.025	-0.095	0.000	0.098
76.000	-0.183	0.148	0.161	0.285	-0.028	-0.104	0.000	0.108

1

DATE: 21 FEB 1995
RUN DESCRIPTION: SIMULATION OF THE HUMAN VOLUNTEER SLED TEST
USING NEWLY DEVELOPED HUMAN JOINT CHARACTERISTICS
VEHICLE DECELERATION: SLED ACCELERATION
CRASH VICTIM: MALE HUMAN 167 LB

CARD A2
CARD A2 **PAGE: 26.00**
CARD C1

SEGMENT REL. ANGULAR DISPLACEMENT (DEG)

TIME	SEGMENT NO. 12 - RUA IN UT REFERENCE				SEGMENT NO. 13 - RLA IN RUA REFERENCE			
(MSEC)	YAW	PITCH	ROLL	RES	YAW	PITCH	ROLL	RES
0.000	0.000	2.000	0.000	2.000	20.746	63.702	32.834	68.145
2.000	0.007	2.005	-0.002	2.005	20.741	63.698	32.828	68.140
4.000	0.022	2.019	-0.009	2.019	20.721	63.685	32.806	68.124
6.000	0.044	2.039	-0.022	2.040	20.686	63.661	32.767	68.094
8.000	0.072	2.066	-0.041	2.067	20.635	63.625	32.710	68.050
10.000	0.104	2.097	-0.066	2.101	20.569	63.580	32.636	67.994
12.000	0.142	2.132	-0.097	2.139	20.490	63.525	32.549	67.927
14.000	0.183	2.172	-0.134	2.184	20.400	63.462	32.448	67.850
16.000	0.229	2.214	-0.177	2.233	20.300	63.391	32.335	67.763
18.000	0.278	2.259	-0.227	2.288	20.190	63.313	32.213	67.667
20.000	0.331	2.307	-0.282	2.349	20.073	63.230	32.082	67.565
22.000	0.388	2.357	-0.342	2.415	19.951	63.142	31.945	67.458
24.000	0.448	2.409	-0.408	2.486	19.824	63.049	31.803	67.345
26.000	0.511	2.463	-0.479	2.563	19.694	62.954	31.657	67.229
28.000	0.578	2.519	-0.555	2.646	19.562	62.856	31.508	67.110
30.000	0.647	2.576	-0.636	2.735	19.427	62.755	31.357	66.988
32.000	0.720	2.634	-0.721	2.829	19.292	62.653	31.204	66.864
34.000	0.795	2.693	-0.811	2.928	19.155	62.548	31.050	66.737
36.000	0.872	2.753	-0.905	3.033	19.017	62.442	30.894	66.609
38.000	0.952	2.814	-1.004	3.143	18.878	62.334	30.738	66.479
40.000	1.034	2.875	-1.106	3.258	18.739	62.225	30.581	66.348
42.000	1.119	2.936	-1.211	3.378	18.600	62.115	30.423	66.215
44.000	1.205	2.997	-1.321	3.502	18.460	62.003	30.266	66.081
46.000	1.293	3.059	-1.433	3.630	18.321	61.890	30.107	65.946
48.000	1.384	3.120	-1.548	3.763	18.181	61.777	29.949	65.810
50.000	1.475	3.180	-1.667	3.899	18.042	61.662	29.791	65.673
52.000	1.569	3.240	-1.788	4.039	17.903	61.546	29.634	65.535
54.000	1.662	3.300	-1.912	4.182	17.776	61.439	29.488	65.407
56.000	1.745	3.357	-2.041	4.323	17.692	61.368	29.393	65.323
58.000	1.819	3.413	-2.173	4.462	17.663	61.343	29.359	65.293
60.000	1.892	3.470	-2.306	4.604	17.659	61.340	29.356	65.290
62.000	1.972	3.530	-2.437	4.752	17.651	61.333	29.347	65.282
64.000	2.059	3.594	-2.567	4.906	17.633	61.318	29.326	65.263
66.000	2.150	3.663	-2.696	5.067	17.604	61.293	29.293	65.234
68.000	2.245	3.738	-2.825	5.235	17.565	61.259	29.248	65.194
70.000	2.344	3.820	-2.953	5.410	17.516	61.217	29.193	65.144
72.000	2.445	3.910	-3.081	5.592	17.459	61.168	29.127	65.086
74.000	2.549	4.008	-3.209	5.781	17.394	61.111	29.053	65.019
76.000	2.654	4.116	-3.337	5.978	17.322	61.048	28.970	64.944

1

DATE: 21 FEB 1995
RUN DESCRIPTION: SIMULATION OF THE HUMAN VOLUNTEER SLED TEST
USING NEWLY DEVELOPED HUMAN JOINT CHARACTERISTICS
VEHICLE DECELERATION: SLED ACCELERATION
CRASH VICTIM: MALE HUMAN 167 LB

CARD A2
CARD A2 **PAGE: 27.00**
CARD C1

JOINT PARAMETERS

	JOINT NO. 5 - RH							JOINT NO. 8 - LH							
TIME (MSEC)	STATE IPIN	JOINT ANGLES (DEG) FLEXURE	AZIMUTH	TORSION	TOTAL TORQUE (IN. LB.) SPRING	VISCOUS	RES.	STATE IPIN	JOINT ANGLES (DEG) FLEXURE	AZIMUTH	TORSION	TOTAL TORQUE (IN. LB.) SPRING	VISCOUS	RES.
0.000	0.	30.579	-5.345	-3.652	0.000	0.000	0.000	0.	30.579	5.345	3.652	0.000	0.000	0.000
2.000	0.	30.576	-5.345	-3.646	0.000	1.791	1.791	0.	30.576	5.345	3.646	0.000	1.791	1.791
4.000	0.	30.568	-5.344	-3.634	0.000	2.544	2.544	0.	30.568	5.344	3.634	0.000	2.543	2.543
6.000	0.	30.559	-5.340	-3.617	0.000	3.014	3.014	0.	30.559	5.340	3.618	0.000	3.012	3.012
8.000	0.	30.550	-5.333	-3.597	0.000	3.400	3.400	0.	30.550	5.333	3.597	0.000	3.401	3.401
10.000	0.	30.542	-5.325	-3.574	0.000	3.729	3.729	0.	30.542	5.325	3.574	0.000	3.725	3.725
12.000	0.	30.535	-5.315	-3.549	0.000	3.968	3.968	0.	30.535	5.316	3.549	0.000	3.955	3.955
14.000	0.	30.529	-5.305	-3.521	0.000	4.150	4.150	0.	30.529	5.305	3.522	0.000	4.113	4.113
16.000	0.	30.523	-5.293	-3.493	0.000	4.307	4.307	0.	30.523	5.294	3.494	0.000	4.230	4.230
18.000	0.	30.519	-5.281	-3.463	0.000	4.461	4.461	0.	30.519	5.282	3.464	0.000	4.394	4.394
20.000	0.	30.515	-5.268	-3.432	0.000	4.623	4.623	0.	30.514	5.269	3.434	0.000	4.558	4.558
22.000	0.	30.511	-5.255	-3.399	0.000	4.810	4.810	0.	30.511	5.256	3.402	0.000	4.767	4.767
24.000	0.	30.508	-5.242	-3.366	0.000	5.061	5.061	0.	30.508	5.243	3.368	0.000	5.041	5.041
26.000	0.	30.505	-5.228	-3.330	0.000	5.436	5.436	0.	30.505	5.229	3.332	0.000	5.441	5.441
28.000	0.	30.502	-5.213	-3.290	0.000	6.050	6.050	0.	30.502	5.215	3.293	0.000	6.056	6.056
30.000	0.	30.499	-5.197	-3.246	0.000	6.826	6.826	0.	30.498	5.199	3.249	0.000	6.837	6.837
32.000	0.	30.495	-5.179	-3.197	0.000	7.501	7.501	0.	30.495	5.181	3.199	0.000	7.514	7.514
34.000	0.	30.492	-5.160	-3.143	0.000	8.085	8.085	0.	30.492	5.162	3.146	0.000	8.101	8.101
36.000	0.	30.488	-5.140	-3.086	0.000	8.613	8.613	0.	30.488	5.141	3.088	0.000	8.624	8.624
38.000	0.	30.484	-5.118	-3.025	0.000	9.092	9.092	0.	30.483	5.119	3.027	0.000	9.115	9.115
40.000	0.	30.479	-5.094	-2.961	0.000	9.515	9.515	0.	30.478	5.096	2.963	0.000	9.544	9.544
42.000	0.	30.474	-5.070	-2.894	0.000	9.868	9.868	0.	30.473	5.071	2.896	0.000	9.905	9.905
44.000	0.	30.468	-5.045	-2.826	0.000	10.158	10.158	0.	30.467	5.046	2.827	0.000	10.204	10.204
46.000	0.	30.462	-5.019	-2.755	0.000	10.415	10.415	0.	30.461	5.020	2.756	0.000	10.466	10.466
48.000	0.	30.454	-4.993	-2.683	0.000	10.657	10.657	0.	30.453	4.993	2.684	0.000	10.711	10.711
50.000	0.	30.446	-4.966	-2.609	0.000	10.879	10.879	0.	30.445	4.965	2.609	0.000	10.934	10.934
52.000	0.	30.437	-4.938	-2.534	0.000	11.036	11.036	0.	30.436	4.937	2.534	0.000	11.090	11.090
54.000	0.	30.428	-4.910	-2.457	0.000	11.622	11.622	0.	30.426	4.908	2.457	0.000	11.656	11.656
56.000	0.	30.416	-4.879	-2.375	0.000	12.619	12.619	0.	30.414	4.877	2.374	0.000	12.618	12.618
58.000	0.	30.404	-4.844	-2.285	0.000	13.348	13.348	0.	30.403	4.842	2.285	0.000	13.329	13.329
60.000	0.	30.396	-4.809	-2.195	0.000	12.856	12.856	0.	30.394	4.806	2.195	0.000	12.825	12.825
62.000	0.	30.389	-4.776	-2.111	0.000	11.457	11.457	0.	30.388	4.773	2.111	0.000	11.409	11.409
64.000	0.	30.388	-4.747	-2.038	0.000	9.518	9.518	0.	30.386	4.744	2.039	0.000	9.454	9.454
66.000	0.	30.393	-4.724	-1.980	0.000	7.338	7.338	0.	30.391	4.722	1.981	0.000	7.278	7.278
68.000	0.	30.404	-4.708	-1.939	0.000	5.299	5.299	0.	30.403	4.706	1.940	0.000	5.245	5.245
70.000	0.	30.420	-4.698	-1.913	0.000	3.800	3.800	0.	30.419	4.696	1.915	0.000	3.765	3.765
72.000	0.	30.441	-4.694	-1.901	0.000	3.529	3.529	0.	30.439	4.693	1.903	0.000	3.559	3.559
74.000	0.	30.467	-4.695	-1.900	0.000	4.407	4.407	0.	30.465	4.695	1.903	0.000	4.404	4.404
76.000	0.	30.500	-4.700	-1.908	0.000	5.826	5.826	0.	30.498	4.701	1.911	0.000	5.852	5.852

1 DATE: 21 FEB 1995

RUN DESCRIPTION: SIMULATION OF THE HUMAN VOLUNTEER SLED TEST
USING NEWLY DEVELOPED HUMAN JOINT CHARACTERISTICS

VEHICLE DECELERATION: SLED ACCELERATION

CRASH VICTIM: MALE HUMAN 167 LB

CARD A2
CARD A2 **PAGE: 37.00**
CARD C1

LS JOINT FORCES & TORQUES ON LUA IN RUA REFERENCE

TIME (MSEC)	JOINT FORCE (LB. 10**2) X	Y	Z	JOINT TORQUE (IN.- LB. 10**2) X	Y	Z
0.000	0.039	-0.059	-0.006	0.810D+00	0.475D+00	-0.594D+00
2.000	0.038	-0.065	-0.027	0.796D+00	0.445D+00	-0.453D+00
4.000	0.035	-0.065	-0.043	0.777D+00	0.421D+00	-0.432D+00
6.000	0.031	-0.064	-0.051	0.758D+00	0.402D+00	-0.413D+00
8.000	0.028	-0.063	-0.055	0.737D+00	0.385D+00	-0.395D+00
10.000	0.026	-0.062	-0.059	0.716D+00	0.370D+00	-0.379D+00
12.000	0.023	-0.061	-0.061	0.695D+00	0.357D+00	-0.364D+00
14.000	0.021	-0.060	-0.063	0.673D+00	0.345D+00	-0.349D+00
16.000	0.019	-0.058	-0.065	0.651D+00	0.334D+00	-0.336D+00
18.000	0.017	-0.057	-0.067	0.630D+00	0.324D+00	-0.323D+00
20.000	0.018	-0.055	-0.070	0.608D+00	0.315D+00	-0.309D+00
22.000	0.017	-0.053	-0.071	0.587D+00	0.306D+00	-0.296D+00
24.000	0.018	-0.051	-0.073	0.566D+00	0.298D+00	-0.284D+00
26.000	0.017	-0.049	-0.074	0.545D+00	0.291D+00	-0.271D+00
28.000	0.017	-0.047	-0.075	0.524D+00	0.284D+00	-0.259D+00
30.000	0.016	-0.046	-0.076	0.504D+00	0.278D+00	-0.247D+00
32.000	0.015	-0.044	-0.076	0.484D+00	0.273D+00	-0.236D+00
34.000	0.015	-0.042	-0.076	0.464D+00	0.268D+00	-0.225D+00
36.000	0.014	-0.040	-0.077	0.445D+00	0.263D+00	-0.214D+00
38.000	0.014	-0.038	-0.077	0.426D+00	0.259D+00	-0.204D+00
40.000	0.013	-0.036	-0.077	0.407D+00	0.255D+00	-0.194D+00
42.000	0.013	-0.034	-0.077	0.389D+00	0.252D+00	-0.185D+00
44.000	0.013	-0.033	-0.077	0.372D+00	0.250D+00	-0.175D+00
46.000	0.012	-0.031	-0.077	0.355D+00	0.248D+00	-0.166D+00
48.000	0.012	-0.029	-0.077	0.338D+00	0.246D+00	-0.157D+00
50.000	0.012	-0.027	-0.077	0.322D+00	0.245D+00	-0.149D+00
52.000	0.013	-0.026	-0.080	0.306D+00	0.244D+00	-0.140D+00
54.000	0.019	-0.025	-0.102	0.288D+00	0.246D+00	-0.153D+00
56.000	0.027	-0.021	-0.104	0.269D+00	0.252D+00	-0.183D+00
58.000	0.033	-0.014	-0.082	0.256D+00	0.253D+00	-0.197D+00
60.000	0.033	-0.011	-0.062	0.250D+00	0.242D+00	-0.182D+00
62.000	0.030	-0.012	-0.061	0.244D+00	0.227D+00	-0.158D+00
64.000	0.027	-0.012	-0.065	0.237D+00	0.210D+00	-0.139D+00
66.000	0.022	-0.012	-0.071	0.229D+00	0.190D+00	-0.124D+00
68.000	0.019	-0.011	-0.075	0.220D+00	0.167D+00	-0.111D+00
70.000	0.016	-0.010	-0.080	0.210D+00	0.142D+00	-0.998D-01
72.000	0.012	-0.009	-0.082	0.199D+00	0.114D+00	-0.903D-01
74.000	0.009	-0.008	-0.089	0:187D+00	0.836D-01	-0.819D-01
76.000	0.005	-0.007	-0.093	0.176D+00	0.505D-01	-0.744D-01
78.000	0.001	-0.005	-0.101	0.163D+00	0.140D-01	-0.676D-01

1

DATE: 21 FEB 1995
RUN DESCRIPTION: SIMULATION OF THE HUMAN VOLUNTEER SLED TEST
USING NEWLY DEVELOPED HUMAN JOINT CHARACTERISTICS
VEHICLE DECELERATION: SLED ACCELERATION
CRASH VICTIM: MALE HUMAN 167 LB
CONTACT FORCES - SEGMENT PANELS VS. SEGMENTS

CARD A2
CARD A2 **PAGE: 38.00**
CARD C1

TIME (MSEC)	PANEL 1 (SEAT CUSHION) DEFL-ECTION (IN.)	NORMAL FORCE (LB.)	FRICTION FORCE (LB.)	RESULTANT FORCE (LB.)	VS SEG 1 (LT) ELLIP 1 CONTACT LOCATION (IN.) (VEH REFERENCE) X	Y	Z	PANEL 1 (SEAT CUSHION) DEFL-ECTION (IN.)	NORMAL FORCE (LB.)	FRICTION FORCE (LB.)	RESULTANT FORCE (LB.)	VS SEG 6 (RUL) ELLIP 6 CONTACT LOCATION (IN.) (VEH REFERENCE) X	Y	Z
0.000	0.455	105.43	0.00	105.43	13.942	0.000	-10.414	0.220	24.06	0.00	24.06	24.627	4.459	-11.535
2.000	0.455	139.34	64.51	153.55	13.941	0.000	-10.414	0.220	24.47	19.05	31.01	24.626	4.459	-11.535
4.000	0.456	153.68	72.41	169.89	13.939	0.000	-10.413	0.220	24.06	21.37	32.18	24.622	4.459	-11.534
6.000	0.457	159.86	75.40	176.75	13.938	0.000	-10.413	0.220	24.03	21.30	32.12	24.619	4.460	-11.534
8.000	0.458	160.93	77.01	178.40	13.936	0.000	-10.413	0.220	23.96	20.93	31.82	24.615	4.460	-11.534
10.000	0.459	160.54	76.96	178.03	13.934	0.000	-10.413	0.219	23.84	20.07	31.16	24.612	4.461	-11.533
12.000	0.460	159.76	75.99	176.91	13.932	0.000	-10.413	0.218	23.67	18.92	30.30	24.609	4.462	-11.533
14.000	0.461	158.68	74.79	175.42	13.930	0.000	-10.412	0.217	23.46	17.91	29.51	24.606	4.463	-11.533
16.000	0.462	157.55	74.41	174.24	13.928	0.000	-10.412	0.216	23.21	17.10	28.83	24.604	4.465	-11.533
18.000	0.463	156.64	73.52	173.04	13.927	0.000	-10.412	0.215	22.94	16.25	28.11	24.602	4.466	-11.532
20.000	0.464	156.21	71.97	171.99	13.925	0.000	-10.412	0.213	22.63	15.35	27.35	24.600	4.467	-11.532
22.000	0.465	155.24	69.97	170.27	13.923	0.000	-10.412	0.212	22.31	14.35	26.52	24.599	4.469	-11.532
24.000	0.466	154.61	67.43	168.67	13.921	0.000	-10.412	0.210	21.97	13.27	25.66	24.597	4.470	-11.532
26.000	0.467	153.90	66.84	167.78	13.919	0.000	-10.411	0.208	21.62	12.91	25.18	24.596	4.472	-11.532
28.000	0.468	151.74	66.10	165.52	13.918	0.000	-10.411	0.206	21.26	12.95	24.89	24.594	4.473	-11.532
30.000	0.468	149.40	64.86	162.87	13.916	0.000	-10.411	0.204	20.88	12.86	24.52	24.592	4.475	-11.531
32.000	0.469	147.14	62.69	159.94	13.914	0.000	-10.411	0.202	20.49	12.60	24.05	24.590	4.477	-11.531
34.000	0.470	145.50	61.14	157.82	13.912	0.000	-10.411	0.200	20.09	12.51	23.66	24.588	4.479	-11.531
36.000	0.470	143.88	59.48	155.69	13.910	0.000	-10.410	0.198	19.77	12.65	23.47	24.586	4.481	-11.531
38.000	0.471	142.34	57.49	153.51	13.909	0.000	-10.410	0.197	19.48	12.73	23.27	24.583	4.484	-11.530
40.000	0.471	140.97	55.07	151.35	13.907	0.000	-10.410	0.195	19.20	12.71	23.02	24.580	4.486	-11.530
42.000	0.472	140.15	52.40	149.62	13.905	0.000	-10.410	0.193	18.94	12.69	22.80	24.576	4.489	-11.530
44.000	0.472	139.35	49.94	148.03	13.903	0.000	-10.410	0.191	18.69	12.95	22.74	24.572	4.492	-11.529
46.000	0.472	138.59	47.92	146.64	13.902	0.000	-10.409	0.190	18.47	13.34	22.78	24.567	4.494	-11.529
48.000	0.473	137.93	46.37	145.51	13.900	0.000	-10.409	0.188	18.27	13.79	22.89	24.562	4.497	-11.528
50.000	0.473	137.62	43.63	144.37	13.898	0.000	-10.409	0.187	18.10	13.85	22.79	24.557	4.500	-11.528
52.000	0.473	138.26	40.48	144.06	13.897	0.000	-10.409	0.186	17.95	13.66	22.56	24.551	4.503	-11.527
54.000	0.474	140.89	37.42	145.78	13.895	0.000	-10.409	0.186	17.86	14.60	23.07	24.545	4.506	-11.526
56.000	0.474	145.82	26.28	148.17	13.894	0.000	-10.409	0.186	25.67	21.35	33.38	24.537	4.509	-11.526
58.000	0.475	150.50	17.52	151.52	13.893	0.000	-10.408	0.187	31.72	21.93	38.57	24.528	4.512	-11.525
60.000	0.476	149.47	10.34	149.83	13.892	0.000	-10.408	0.187	30.24	16.47	34.43	24.519	4.515	-11.524
62.000	0.476	149.56	0.25	149.56	13.891	0.000	-10.408	0.188	30.26	9.64	31.76	24.511	4.519	-11.523
64.000	0.477	156.49	12.48	156.98	13.891	0.000	-10.408	0.189	35.40	3.60	35.58	24.504	4.521	-11.522
66.000	0.478	166.01	11.17	166.39	13.892	0.000	-10.408	0.190	43.42	20.71	48.11	24.497	4.523	-11.521
68.000	0.478	171.51	9.35	171.76	13.893	0.000	-10.409	0.192	50.61	36.18	62.21	24.491	4.525	-11.521
70.000	0.479	174.64	6.56	174.76	13.895	0.000	-10.409	0.193	56.77	51.10	76.38	24.485	4.525	-11.520
72.000	0.481	178.17	2.08	178.18	13.897	0.000	-10.409	0.196	61.75	66.53	90.77	24.481	4.525	-11.520
74.000	0.482	184.13	1.56	184.14	13.899	0.000	-10.409	0.198	63.48	83.69	105.04	24.477	4.524	-11.519
76.000	0.483	190.33	10.73	190.64	13.902	0.000	-10.410	0.200	66.93	102.47	122.39	24.474	4.523	-11.519

1 DATE: 21 FEB 1995
RUN DESCRIPTION: SIMULATION OF THE HUMAN VOLUNTEER SLED TEST
USING NEWLY DEVELOPED HUMAN JOINT CHARACTERISTICS
VEHICLE DECELERATION: SLED ACCELERATION
CRASH VICTIM: MALE HUMAN 167 LB

CARD A2
CARD A2 **PAGE: 45.00**
CARD C1

0 HARNESS SYSTEM BELT ENDPOINT FORCES

	BELT NO. 3 OF HARNESS NO. 1				BELT NO. 4 OF HARNESS NO. 1			
	POINT NO. 28		POINT NO. 45		POINT NO. 46		POINT NO. 49	
TIME (MSEC)	STRAIN (IN./ IN.)	FORCE (LB.)	STRAIN (IN./ IN.)	FORCE (LB.)	STRAIN (IN./ IN.)	FORCE (LB.)	STRAIN (IN./ IN.)	FORCE (LB.)
0.000	0.003203	8.01	0.003203	8.01	0.006708	16.77	0.006708	16.77
2.000	0.003380	8.45	0.002732	6.83	0.006696	16.74	0.006708	16.77
4.000	0.003435	8.59	0.002016	5.04	0.006705	16.76	0.006708	16.77
6.000	0.003440	8.60	0.001676	4.19	0.006718	16.79	0.006708	16.77
8.000	0.003394	8.49	0.001508	3.77	0.006735	16.84	0.006708	16.77
10.000	0.003294	8.24	0.001434	3.58	0.006757	16.89	0.006708	16.77
12.000	0.003147	7.87	0.001421	3.55	0.006783	16.96	0.006708	16.77
14.000	0.002962	7.41	0.001444	3.61	0.006810	17.02	0.006708	16.77
16.000	0.002749	6.87	0.001496	3.74	0.006839	17.10	0.006708	16.77
18.000	0.002520	6.30	0.001583	3.96	0.006870	17.18	0.006708	16.77
20.000	0.001875	4.69	0.001712	4.28	0.006904	17.26	0.006708	16.77
22.000	0.001471	3.68	0.001863	4.66	0.006940	17.35	0.006708	16.77
24.000	0.000826	2.07	0.002020	5.05	0.006976	17.44	0.006708	16.77
26.000	0.000218	0.55	0.002184	5.46	0.007015	17.54	0.006708	16.77
28.000	0.000000	0.00	0.002329	5.82	0.007060	17.65	0.006708	16.77
30.000	0.000000	0.00	0.002478	6.19	0.007112	17.78	0.006708	16.77
32.000	0.000000	0.00	0.002631	6.58	0.007171	17.93	0.006708	16.77
34.000	0.000000	0.00	0.002785	6.96	0.007234	18.08	0.006708	16.77
36.000	0.000000	0.00	0.002931	7.33	0.007300	18.25	0.006708	16.77
38.000	0.000000	0.00	0.003073	7.68	0.007370	18.42	0.006708	16.77
40.000	0.000000	0.00	0.003208	8.02	0.007442	18.61	0.006708	16.77
42.000	0.000000	0.00	0.003346	8.37	0.007515	18.79	0.006708	16.77
44.000	0.000000	0.00	0.003500	8.75	0.007587	18.97	0.006744	16.86
46.000	0.000000	0.00	0.003635	9.09	0.007658	19.14	0.006791	16.98
48.000	0.000000	0.00	0.003737	9.34	0.007729	19.32	0.006845	17.11
50.000	0.000000	0.00	0.003818	9.54	0.007799	19.50	0.006903	17.26
52.000	0.000000	0.00	0.003896	9.74	0.007866	19.66	0.006963	17.41
54.000	0.000000	0.00	0.003959	9.90	0.007924	19.81	0.007023	17.56
56.000	0.000000	0.00	0.004016	10.04	0.007967	19.92	0.007079	17.70
58.000	0.000000	0.00	0.004211	10.53	0.007985	19.96	0.007129	17.82
60.000	0.000000	0.00	0.004450	11.13	0.007993	19.98	0.007167	17.92
62.000	0.000000	0.00	0.004582	11.45	0.007989	19.97	0.007193	17.98
64.000	0.000000	0.00	0.004521	11.30	0.007944	19.86	0.007207	18.02
66.000	0.000000	0.00	0.004129	10.32	0.007827	19.57	0.007211	18.03
68.000	0.000000	0.00	0.003533	8.83	0.007646	19.12	0.007212	18.03
70.000	0.000000	0.00	0.002891	7.23	0.007418	18.55	0.007212	18.03
72.000	0.000000	0.00	0.002126	5.32	0.007159	17.90	0.007208	18.02
74.000	0.000000	0.00	0.001236	3.09	0.006872	17.18	0.007208	18.02
76.000	0.000000	0.00	0.000237	0.59	0.006533	16.33	0.007208	18.02
78.000	0.000000	0.00	0.000000	0.00	0.006137	15.34	0.007208	18.02

1 DATE: 21 FEB 1995
RUN DESCRIPTION: SIMULATION OF THE HUMAN VOLUNTEER SLED TEST
USING NEWLY DEVELOPED HUMAN JOINT CHARACTERISTICS
VEHICLE DECELERATION: SLED ACCELERATION
CRASH VICTIM: MALE HUMAN 167 LB
0 CONTACT FORCES - SEGMENT NO. 6 (RUL) VS. SEGMENT NO. 9 (LUL)

CARD A2
CARD A2 **PAGE: 47.00**
CARD C1

TIME (MSEC)	DEFL-ECTION (IN.)	NORMAL FORCE (LB.)	FRICTION FORCE (LB.)	RESULTANT FORCE (LB.)	CONTACT LOCATION (IN.) SEG. 6 LOCAL REFERENCE X	Y	Z	SEG. 9 LOCAL REFERENCE X	Y	Z
0.000	0.000	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000
2.000	0.000	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000
4.000	0.000	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000
6.000	0.000	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000
8.000	0.000	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000
10.000	0.000	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000
12.000	0.000	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000
14.000	0.000	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000
16.000	0.000	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000
18.000	0.000	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000
20.000	0.000	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000
22.000	0.000	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000
24.000	0.000	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000
26.000	0.000	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000
28.000	0.000	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000
30.000	0.000	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000
32.000	0.000	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000
34.000	0.000	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000
36.000	0.000	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000
38.000	0.000	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000
40.000	0.000	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000
42.000	0.000	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000
44.000	0.000	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000
46.000	0.000	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000
48.000	0.000	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000
50.000	0.000	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000
52.000	0.000	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000
54.000	0.000	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000
56.000	0.000	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000
58.000	0.000	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000
60.000	0.000	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000
62.000	0.000	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000
64.000	0.000	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000
66.000	0.000	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000
68.000	0.000	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000
70.000	0.000	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000
72.000	0.000	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000
74.000	0.000	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000
76.000	0.000	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000
78.000	0.000	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000

APPENDIX B

Developing New Deformable Segment Models

There are three steps to creating a deformable body model for the ATB:

1) Develop a finite element model of the segment and perform modal analysis to determine the first two natural frequencies and their corresponding mode shapes.
2) Write an ASCII file containing the nodal positions, nodal masses, frequencies, and mode shapes. The user must make sure that this file has the format described in section B.2.
3) Modify the ATB input file according to the ATB Input Description.

B. 1 Segment Finite Element Model

A finite element model of the segment must be created and modal analysis must be performed to determine its natural frequencies and mode shapes. The required information are number modes, number of nodes, nodal positions, nodal masses, frequencies, and mode shapes.

B.2 Deformable Body Input Data File

The finite element modal analysis information must be written in an unformatted ASCII file in the following order:

1) number of nodes (NNOD) and number of modes (NMOD);	No. of data = 2
2) nodal positions with respect to the body reference frame;	No. of data = 3*NNOD
3) nodal masses;	No. of data = NNOD
4) natural frequencies in Hz;	No. of data = NMOD
5) mode shapes (eigenvectors);	No. of data = 6*NNOD*NMOD

This procedure has been simplified when ANSYS® or ALGOR® is used. A FORTRAN program named "atbalgor.for" has been written which creates the required ASCII file and assigns the name "filename.dat" using the "filename.l" & "filename.frq" files produced by ALGOR. Another FORTRAN program named "atbansys.for" has also been written for ANSYS which also creates the same ASCII file. These programs are included with the ATB model.